TENNEY ENGINEERING, INC.
1090 SPRINGFIELD ROAD
UNION, NEW JERSEY 07083

INSTRUCTION KIT FOR TENNEY TEMPERATURE HUMIDITY CHAMBERS WITH TENNTROL II

INCLUDED

Basic Manual

Bulletin #145 TennTrol II

Specification Bulletin Applying to Chamber

TennTrol II Technical Information

TennTrol II Calibration

Servicing Cascade Refrigeration Systems

Drawings

Vapor-Flo Manual

NOTE: "Servicing Cascade. . ." applies only to chambers with two compressors.

Tenney
ENGINEERING, INC.

Bulletin #101S
3 Cubic Foot
Benchtop Test Chamber

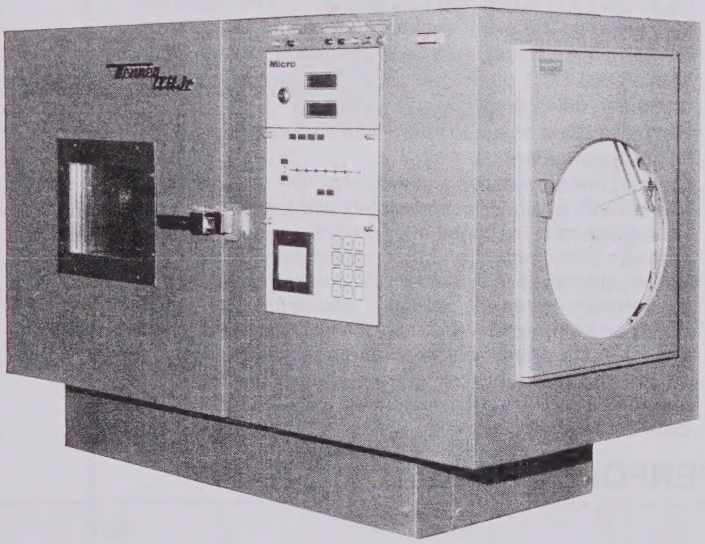
Benchtop Model...

TH Jr.

Wide Range, Temperature & Humidity Environmental Test Chamber with NEW TennTrol II Total Digital Instrumentation Control System

The TH Jr. is a completely self-contained, temperature and humidity benchtop test chamber that offers wide range performance and proven reliability at modest cost. It is ideal for laboratory use in product development, quality assurance, incubation, research, electronic and MIL-STD testing, as well as other applications requiring precise control of temperature and humidity.

The unit utilizes mechanical refrigeration and provides a three cubic foot workspace volume in a compact size. Simplicity of design allows for virtually maintenance-free operation.



TH Jr. shown with optional instrumentation

Workspace: 16½"W×20"H×15¾"D
Temperature Range: −12°C to +93°C
Humidity Range: 20% to 98%

The Largest and Most Experienced Manufacturer of High Technology Environmental Test Equipment
1090 Springfield Rd., P.O. Box 3142, Union, New Jersey 07083 • (201) 686-7870

CONSTRUCTION

The TH Jr. utilizes a heavy gauge, reinforced heliarc welded stainless steel interior for strength and durability. The insulated workspace area is constructed with mass type fiber glass for low heat transfer and Vapor-Weld walls for impermeability to moisture.

Heavy gauge exterior provides an attractive two-tone blue, washable finish. Unit features a 2" (5cm) diameter accessory port with plug and a six foot grounded electrical cord. All wiring is numbered and in accordance with NEC. Full opening lap-type door with double concentric door gaskets, for tight sealing, is provided. This door is hinged and removable offering quick and easy loading and unloading.

STANDARD FEATURES

- TennTrol II is a total digital instrumentation control system. It includes push-to-set multiturn potentiometers and 3½ digit LED display that indicates setpoint and actual conditions. Temperature in °C, humidity in direct % RH, when applicable.
  Automatic logic functions are built-in to select the proper operating modes, selecting refrigeration, heating and humidity modes, as required, to achieve the desired chamber environment.
  Also, built-in (for humidity models only) is state-of-the-art logic circuits that automatically select humidity and dehumidify operating modes. This is accomplished thru a signal conditioner that converts dry/wet bulb signals to direct %RH.
  Self diagnostic interrogation to display percentage output of heating, cooling and humidity.
  Temperature alarm circuit with push-to-set adjustments (high/low) and visual and audible alarms. The digital display will read the alarm setpoints and actual temperature. Contacts are also available to deenergize test items.
  Multiplexed BCD output connector for external control of computer, data logger, etc.
- Hot gas mullion heater to retard frost on door gasket.
- RFI free instrument.
- Unitized instrumentation and control panel.
- Vapor-Flo®, a humidification system which precisely regulates moisture in the chamber by controlling vapor migration between the humidity generator and the cabinet.
- Tenneyairesweep, a system which uniformly conditions the environment within the insulated enclosure. The system draws air from near the bottom of the workspace and conditions it to the proper temperature and humidity. The air is discharged through a grille work at ceiling level of the chamber and a uniform air flow pattern is achieved throughout the chamber.
- Hermeticool®, an accessible hermetic refrigeration system incorporating accurately calibrated capillary tubes in lieu of mechanical expansion valves.
- High temperature cutout to protect chamber.
- Nichrome heaters, designed to provide rapid response to instrument demand.
- Tenney one-year warranty.

OPTIONAL FEATURES

- MicroTenn®, microprocessor programmer-controller, automatically performs time-related programs. Replaces cams and punched tape devices.
- TempGard® III redundant temperature alarm system. Guards against out-of-tolerance temperatures in the chamber. Protects chamber and test specimen.
- Recording instruments
- Manual window wiper
- Thermal pane viewing window
- Transport cart with rubber casters
- Interior light
- Themocouple or electrical terminals
- Special connectors
- Additional or larger ports, or glove ports
- Removable shelves
- Mineral deionizer, extra deionizer cartridges
- One-gallon water tank for humidifier
- Humidity water recirculator
- Two-point programming for temperature cycling
- Pressure taps and gauges

PERFORMANCE DATA

Heating Rates

24 to 65°C	15 minutes
24 to 93°C	30 minutes
−12 to 38°C	10 minutes
−12 to 93°C	40 minutes

Cooling Rates

24 to 2°C	20 minutes
24 to −7°C	40 minutes
24 to −12°C	70 minutes
93 to 38°C	20 minutes
93 to 24°C	25 minutes
93 to 2°C	50 minutes
93 to −7°C	75 minutes
93 to −12°C	120 minutes

Capacity for holding live load during temperature performance

24°C	275 watts
10°C	170 watts
−7°C	45 watts
−12°C	5 watts

Control of conditions is as indicated on instrumentation furnished with chamber. Minor performance variations with window and accessories. Performance data is based on ambient temperature of +24°C at sea level, on 60 Hertz operation. For 50 Hertz operation, performance will be approximately 17% less. Under certain programming conditions, stated rates of change may vary.

Temperature range
−12°C to +93°C
Humidity range
20% to 98% in the dry bulb range +20°C to +85°C limited by a +3°C dewpoint.
Control tolerance
+0.3°C (wet and dry bulb)
Exterior dimensions
45"W×30"H×20¾"D (114cm×76cm×53cm)
Interior dimensions
16½" W×20" H×15¾" D (42cm×51cm×40cm)
Power requirements
115-1-60 15 amp fuse recommended
Water input
Negligible Consumption
Approximate Shipping Weight
275 lbs. (125 KGS)

All Tenney chambers are available on a direct leasing basis

In line with our policy of continual product improvement, Tenney Engineering, Inc. reserves the right to incorporate and use equipment and material to conform with the latest design of its products, and in keeping with the specifications of this equipment.

Printed in U.S.A.

Made in our NJ plant

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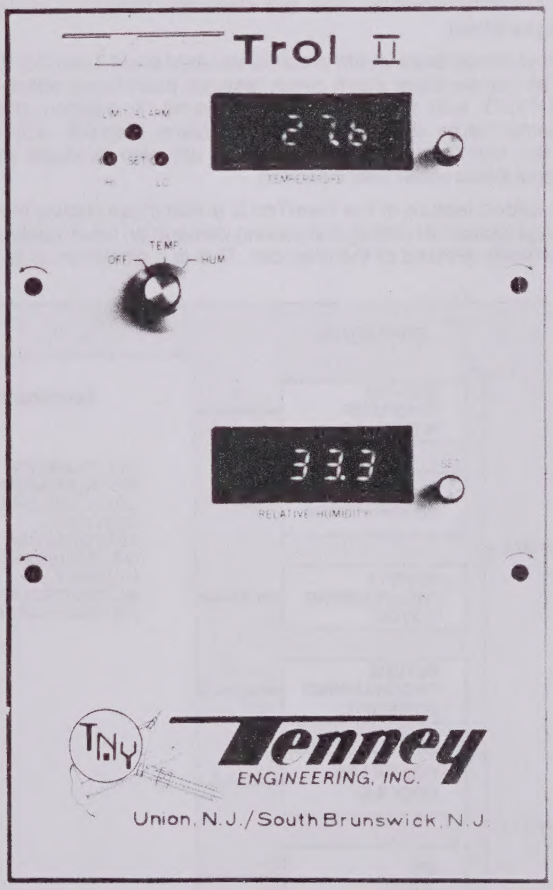
Tenney ENGINEERING, INC.

Bulletin #145A
Tenn Trol II

Tenn Trol™ II

TennTrol II is a Total Digital Instrumentation Control System

Now standard on all Tenney temperature and temperature/humidity environmental test chambers (except Model T Jr.)



FEATURES

- Direct reading LED display to 0.1°C
- Push-to-set adjustments (temperature/humidity)
- Reads-Actual and setpoint, temperature °C, humidity in direct % RH
- High/Low limit alarms, deenergizes chamber, protects item under test
- Built-in logic circuits
- Solid state switching
- Multiplexed BCD output available

DESCRIPTION

TennTrol II is a new total digital instrumentation control system that is now standard on all Tenney temperature, temperature/humidity and altitude environmental test chambers.

This state-of-the-art control system features a 3½ digit LED display for reading temperature, temperature setpoint and when the chamber is equipped with humidity, an additional 3 digit LED display reads actual % relative humidity as well as the humidity setpoint.

When used with a temperature only chamber, Tenn Trol II includes a bidirectional time proportional digital temperature controller as well as state-of-the-art logic circuits to provide automatic selection of the heating and cooling functions. The logic outputs select heating and refrigeration modes, as required to achieve the desired chamber environment. This eliminates confusing mode selecting switches.

For chambers with temperature and humidity, TennTrol II uses a humidity bidirectional time proportional digital controller in addition to the one used for temperature. In order to read direct % RH, a signal conditioner converts dry/wet bulb and temperature measurements to a signal that is linear with respect to humidity in direct % RH. As in the temperature-only version, a built-in logic circuit not only selects refrigeration and heating modes, it also automatically selects humidity and dehumidify operating modes to achieve the desired humidity condition. This also eliminates confusing mode selecting switches.

A high/low temperature alarm circuit is standard on all TennTrol II units. This temperature alarm circuit features push-to-set adjustments (HI/LO) with visual and audible alarms. In addition, the digital temperature display will read the alarm setpoints when setting the high/low conditions. Contacts are also available to deenergize items under test, if desired.

Another added feature of the TennTrol II is that it can display the percentage output of heating and cooling demand or, when applicable, humidity demand of the chamber. This is a significant diagnostic aid in terms of monitoring the performance of the chamber conditioners.

OPERATION

Operation is simple. The operator simply turns the selector to either "temperature" or "humidity" when the chamber is equipped with humidity. He then pushes in on the muliturn potentiometer knob located near the temperature or humidity indicator, rotating it until the desired setpoint appears on the LED display.

To set the high/low alarms you use a small screwdriver on the adjustable push-to-set potentiometers located on the front panel. When the screwdriver is pushed in, the temperature display will read the alarm setpoint.

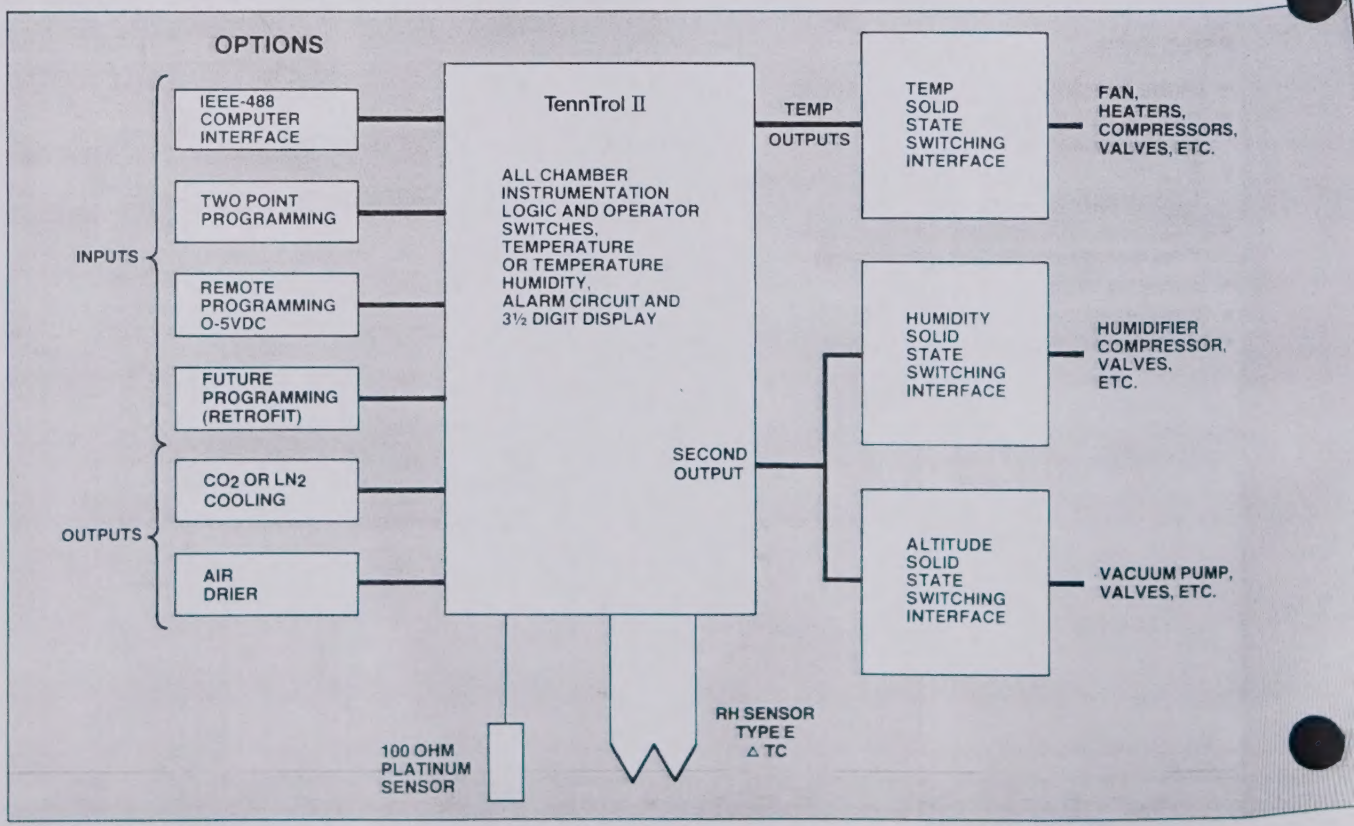
In addition to a red alarm light on the front panel of the Tenn Trol II, three indicator lights are located directly above the Tenn Trol II panel. A red warning light tells when the instrument is in alarm. A green light indicates normal; and a white light tells that alarm silence mode is selected.

That's all. The chamber then performs automatically. The solid state TennTrol II selects the required conditioning modes while maintaining setpoints accurately.

TennTrol II IEEE-488 Interface Option

A sophisticated system, the IEEE-488 interface includes a microprocessor based signal controller, a digital-to-analog setpoint converter, a BCD temperature feedback system, and auxiliary event switching. This system coupled with the inherent automation of TennTrol II, provides full computer programming capability and integration of a total automatic testing facility.

A second loop similar to above can be provided for relative humidity.



In line with our policy of continual product improvement, Tenney Engineering, Inc. reserves the right to incorporate and use equipment and material to conform with the latest design of its products, and with the specifications of this equipment.

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SCOPE

This manual covers use and function of Tenney test cabinets with TennTrol II, designed to perform environmental testing at controlled high and low temperatures and controlled high and low humidities.

ADDITIONAL MATERIAL FURNISHED

Specific installation details, including dimensions and required utilities are found in the drawings which accompany this instruction set and are considered part of it. These drawings are also important to the user because they carry parts lists which are useful to maintenance personnel.

UNPACKING

The chamber is commercially packed and requires no special unpacking technique.

Caution: Handle and transport the chamber in a reasonably upright position. Do not carry it on its back, front or any side. To do so would strain the refrigeration compressor mounts.

ASSEMBLY

The facility is completely assembled and tested at Tenney prior to shipment. No additional assembly is required at the point of use.

INSTALLATION

The chamber requires no special installation procedures. Set it up and level it. Place the cabinet where its air-cooled refrigeration condenser will receive fresh air. Connect it to a power source as specified on the nameplate. Read the section of this manual entitled

"Watch That Line Voltage".

Level the chamber. Inspect the refrigeration compressors. If they are externally sprung, loosen the hold-downs until the units float freely on their springs.

Make the electrical hook-ups shown on the electrical drawing. It's a good idea to make your connections through a close-by disconnect. This is not supplied by Tenney unless specifically ordered.

If your unit is water-cooled, connect to the water-in fitting at the rear. Connect the water-out to an open drain. Connect the Vapor-Flo humidity generator and wick pan feed to a supply of dead soft or demineralized water. Don't use distilled water. Please read "About the Water Supply" in our bound-in booklet "How to Use and Service Tenney Vapor-Flo Humidity Generators." It is important that the water be very low in minerals, otherwise the humidifier will become encrusted.

Remove the sheet metal cover over the conditioner inside the chamber workspace. Inspect the conditioner fan, making sure that it rotates freely. See that there is water in the wick pan, that the wet sock is wet and is covering the wet bulb sensor. This is important.

Inspect the heat limiter located in the conditioner. Be sure the limiter is in its clip. (It looks like a cartridge fuse.)

The insulating cover over the float bowl on the Vapor-Flo humidifier is taped in place during shipment. Remove the cover and make sure the water level in the bowl is correct. If the float was bent in shipment, water may dribble out of the unit, or, alternately, there may be insufficient liquid in the bowl. Read the Vapor-Flo instructions which accompany this instruction.

NOTE ON WET WICK INSTALLATION

Temperature-humidity chambers are shipped from Tenney with a clean, fresh wet wick installed. The wick is slipped over the wet bulb differential sensor located over the wet wick pan.

The wet wick assembly is located in the conditioner sheet metal, and is reached by removal of the covering grille. The dry bulb sensor or sensors are usually positioned about three inches above the wet sensor.

When changing a wick, slip off the old one and slip a new cloth sock into position, being careful to cover the sensor. Arrange the trailing wick portion of cloth to dip into the water of the wick pan underneath. Naturally, the entire wick must be wet or the sensor will give a response indicating relative humidity higher than that actually in the workspace.

PREPARATION

No special preparation is required after the chamber is set up, leveled and connected to its source of water and power. It is then ready to operate on a shake down run as described in the section of this manual entitled "Operate The Chamber As Soon As It Is Received".

WATCH THAT LINE VOLTAGE

One of the most common causes of chamber malfunction is low line voltage at the chamber terminals. Be careful that your facility is connected to a circuit with adequate ampacity to handle the load. Tenney chambers are designed to operate on the following voltages with the noted maximums and minimums applying to nameplate nominal at 60 hz.

115 volts nominal	104v. minimum	127v. maximum
230 volts nominal	208v. minimum	253v. maximum
208 volts nominal	200v. minimum	218v. maximum

Chambers rated 208 volts should never be operated below 200 volts as a bare minimum. If voltage falls to that level, or close to it, at maximum operation, we strongly suggest that you fit the chamber with a suitable boosting transformer. Tenney can recommend and quote on the correct transformer.

OPERATE THE CHAMBER AS SOON AS IT IS RECEIVED

We suggest that when this chamber is first set up and ready to run, that you operate it in various modes before using it as a test facility.

Pull the chamber down to its lowest rated temperature and allow it to stabilize for a half hour. Then, heat it to its highest rated temperature, again allowing it to stabilize. Finally, operate with both high and low humidity.

Operating the chamber as described above will assure that it is operable and that it was not damaged in transit.

OPERATING WITH AN ACTIVE HEAT LOAD

Remember that when testing with an active live load such as an energized electronic assembly, its generated heat must be removed. If it is not, chamber temperature will rise. Tenney chambers are well insulated; an active heat load in the workspace will raise chamber temperature quickly unless refrigeration is available to remove the heat.

Where you perform tests on an energized specimen which gives off heat, and where runaway high temperature would damage its components, consider protecting the specimen with customer's contact closure on relay 2CR. This closure is shown on the electrical schematic drawing. If redundant protection is required, install a Tenney TempGard. Details about TempGard are available from Tenney.

START-UP

Connect the chamber to its source of power. In most cases it is wise to do this through a nearby master disconnect switch.

When the chamber is connected, the small instrumentation cooling fan will run. It will do so regardless of whether the circuit breaker is open or closed, and regardless of selector switch settings. The chamber must be disconnected in order to stop the small fan.

When the chamber is connected to its power source, the white power light and green normal light are on. The red alarm light and white silence light are out. If the silence light is on, throw the silence switch to its other position.

Close the circuit breaker. This will apply power to the balance of the control circuitry. Responses to the rotating selector switch are now as follows:

OFF: All conditioning is disabled. Temperature is correctly displayed. However, temperature setpoint display (when selected) is meaningless. Humidity display is blank.

TEMPERATURE: Temperature conditioning is activated. Temperature display and setpoint display (when selected) are correct. Humidity display remains blank.

HUMIDITY: Both temperature and humidity conditioning are activated. Temperature display and setpoint display (when selected) are correct. Humidity display is correct; and humidity setpoint display (when selected is correct.

Setting the alarm Circuit (If Necessary)

The high-low alarm was properly adjusted at Tenney. However, if you wish to affirm its setting or readjust, do as follows when the chamber is energized.

1. With a small screwdriver, press in on the hi-set limit alarm screw. Alarm setting will appear on the display. Rotate the screw to enter desired high alarm setpoint. The temperature you select must be slightly higher than the highest temperature you plan to simulate in the chamber. Otherwise, the chamber will be shut down by false alarms.

2. Using the same technique, adjust the low alarm setpoint slightly lower than lowest operating temperature.

CHAMBER OPERATION (Temperature Only)

1. Close the circuit breaker.

2. Select temperature on the rotating mode switch.

3. Push in on the temperature setpoint knob, and dial wanted temperature setpoint. Setpoint will appear on the digital display. When you release the knob, actual chamber temperature will appear on the display. The chamber will now simulate temperature.

CHAMBER OPERATION (Temperature-Humidity)

1. Close the circuit breaker.

2. Select humidity on the rotary mode switch.

3. Push in on the temperature setpoint knob, and dial wanted temperature setpoint. Release the knob.

4. Push in on the humidity setpoing knob, and dial wanted humidity setpoint. Release the knob. The chamber will now simulate temperature and relative humidity.

WHAT THE PILOT LIGHTS INDICATE

The chamber has several indicator lights. Here is what is indicated as each glows:

1LT, White, Power: The chamber is connected to its source of power.

2LT, Green, Normal: Power is applied to the controls, and the situation in the chamber is normal. This light will extinguish if the heat limiter opens. It will also extinguish if the high-low alarm goes into alarm state.

4LT, Red, Alarm: Temperature in the chamber is out of tolerance either high or low. Alternately, the heat limiter has opened. When this light glows, contactor 1CON has been tripped open, and possibly, circuit breaker 1CB has also tripped open. The chamber is disabled.

5LT, White, Silence: The silence switch is thrown to the position which silences the buzzer when the alarm system is in out-of-tolerance condition, either high or low. However, when the silence light glows, the buzzer will buzz when the alarm system is safe. This ring-back feature reminds the operator to return the switch to its normal position.

3LT, Red, Over Temp: The heat limiter has opened, tripping open the circuit breaker, shutting down the chamber. This light will not go on

when the limit alarm goes to alarm state.

THE HEAT LIMITER HL

Looking like a fuse, and located in the conditioning compartment, the heat limiter protects the chamber against temperatures above its design limit. If it burns out, the operator must replace it with a new limiter.

Upon burning open, heat limiter HL deenergizes green pilot light 2LT, deenergizes contactor 1CON, and deenergizes relay 2CR.

Deenergizing of contactor 1CON removes power from the control circuits, shutting down the chamber. However, opening of 1CON does not deenergize the 115 volt instrument circuits, consequently a shock hazard remains.

Deenergizing of relay 2CR opens the customer's closure contact, deenergizing whatever load the customer has connected through these contacts. Relay 2CR, through its normally-closed contact and through resistor 2R, applies voltage to a trip pole in circuit breaker 1CB. After a short delay, breaker 1CB trips open. Function of tripping open 1CB is to act as a redundant safety device in the event the contactor fails to open quickly enough.

To restore conditioning, replace the heat limiter, make sure the circuit breaker is closed, then press reset push button 1PB.

Caution: When replacing the limiter, make sure all power is disconnected from the chamber.

THE LIMIT ALARM

High and low limits are adjusted by push-to-set screws marked "HI" and "LO" on front of the TennTrol II panel. Adjustment of alarm setpoints was described under "Setting the Alarm Circuit", earlier in this instruction.

Conditioning is restored by closing of the circuit breaker (if open) and pressing of the reset push button.

If "Silence" switch 1SS is in silence position, the buzzer will not sound, but the red light will glow. When the Silence switch is in "silence" position, and TempGard is in safe state, the buzzer will sound. The ring-back feature reminds the operator to throw the switch back to normal position.

RESET AFTER POWER INTERRUPTION

This chamber has the Carling 5-pole circuit breaker as circuit breaker 1CB. Pole #1 serves as the means of tripping open the breaker when the high cutout opens. In the 5-pole Carling breaker, applying voltage to pole #1 causes the breaker to trip open all its poles simultaneously.

Assume that power has been off and is restored. There is the probability that the normally-closed contact in relay 2CR would immediately trip open breaker 1CB before 2CR had time to transfer. False trip-out is prevented by resistor 2R. This resistor limits current to the breaker's pole #1. The breaker's time constant depends upon current. Therefore, by limiting current to pole #1, the breaker is delayed from opening. This gives relay 2CR ample time to transfer.

Note: Pole #1 is intended solely to trip open the breaker when an out-of-tolerance condition occurs. This pole does not protect a circuit.

Automatic reset is also performed by time delay 1TC and control relay 1CR.

When power is restored to instrumentation, time delay 1TC refrains from conducting for several seconds. During that time, relay 1CR is deenergized,

and its normally-closed contact energizes and closes contactor 1CON, energizing the system. Contactor 1CON also electrically latches itself on through one of its own contacts. After the delay 1TC energizes relay 1CR, but the contactor remains closed because of its electrical latch.

TENNTROL TECHNICAL FUNCTIONS

Heat Control:

The heaters are energized in time proportioned mode by triac 1TIF-03. The triac receives proportioning signals from switching module 1SM-03 whenever chamber temperature is below setpoint.

Cooling Control Two Stage Chambers (Cascade):

Switching module 1SM-06 causes triac 1TIF-06 to conduct when internal logic in TennTrol determines that cooling is required. In response, 1TIF-06 energizes the condenser motors and high stage compressor. Module 1SM-05, triac 1TIF-05 and pressure switch 3PS then energize the low stage compressor. (This prevents both compressors from hitting the line at the same instant.)

When chamber temperature falls below about 20°C, module 1SM-08 conducts, arming 1SM-07 and energizing the window heater. 1SM-07 then modulates refrigeration on a time proportioned basis by operating full main coil solenoid valve 8SOL.

Dehumidification, Two Stage Chambers

When internal logic determines that dehumidification is required, switching module 1SM-06 energizes the high stage refrigeration system. Humidity control logic then operates through module 2SM-14, feeding the dehumidification coil through solenoid valve 4SOL.

Cooling Control, Single Stage Chambers:

Switching module 1SM-06 functions as described above, turning on the condenser motors and compressor. 1SM-08 conducts when chamber temperature falls below about 20°C, arming 1SM-07 and energizing the window heater. 1SM-07 then modulates cooling on a time proportioning basis. To cool the chamber, 1SM-07 opens full ambient coil valve 1SOL while simultaneously closing artificial loading valve 11ASOL.

Valve 11ASOL is normally-open, being closed when energized.

Dehumidification, Single Stage Chambers

When internal logic determines that dehumidification is required, switching module 1SM-06 energizes the refrigeration system. Humidity control logic then operates through module 2SM-14, feeding the dehumidification coil through solenoid valve 4SOL.

PREVENTIVE MAINTENANCE

Since the refrigeration system is sealed and the instrumentation is solid state, very little maintenance is required on the temperature humidity chamber. However, the following preventive maintenance steps are suggested once each three (3) months:

1. Clean the refrigeration condenser with a vacuum cleaner and brush.
2. Inspect and clean the condenser fan. Make sure it spins freely.
3. Inspect and clean the conditioner fan. Make sure it spins freely.
4. Clean the inside of the chamber with Tenney's HumiClean, as required.
5. Inspect the door gasket, making sure the door seals well.

6. Adjust the door latch, if the door does not seal well. If adjustment of the latch does not make the door close tightly , replace the gasket.

7. Disconnect the electric power. Inspect inside the machinery compartment, looking for loose electrical connections, frayed wires, loose components, and the like.

8. Inspect the electric heater inside the conditioner, looking for sagging elements, broken insulators or other defects. Inspect the heat limiter, making sure that its contacts are bright and clean.

Note: Before maintaining the humidifier, please peruse our booklet "How to Use and Service Tenney Vapor-Flo Humidity Generators." The important points in preventive maintenance for the Vapor-Flo are these:

1. Always feed the humidifier with demineralized or distilled water.

2. Periodically clean the boiler chamber with Tenney's HumiClean or other boiler cleaner.

3. Keep the bobby float valve clean so that the reservoir does not overflow.

4. Inspect the level of water in the glass reservoir periodically as the unit operates. Make sure water covers the heater elements.

5. Periodically measure current drawn by the immersion heater.

6. Periodically inspect the chamber, making sure that a vent is open when the humidifer is generating vapor. Lack of a vent will prevent vapor from displacing air in the workspace.

IN CASE OF TROUBLE

Tenney facilities have conductors carrying dangerous voltage with heavy current carrying capacity. Be careful when trouble-shooting.

The main circuit breaker opens the circuit to some of the controls. However, many power circuits remain hot and are dangerous unless a main disconnect switch is open or the chamber disconnected from its power source.

Don't take chances. Before working on a machine, open the main disconnect switch and tag it with a red tag saying "DANGER - DO NOT CLOSE THIS SWITCH." Otherwise, unplug or disconnect the chamber.

Our refrigeration systems are sealed and require little service. If you suspect a malfunction, write or call Tenney's Service Department. Unless you are expert in the refrigeration art, don't tamper.

Insufficient cooling, increasing vibration, compressor overheating and constant compressor loading are signs of trouble.

But note: This Tenney facility is designed to operate with the compressors locked on continuously whenever cooling mode is selected by TennTrol logic. Don't be alarmed about the compressor running for long periods. The purpose is to prevent unnecessary cycling.

Before writing or phoning Tenney, inspect the system superficially: Be sure the condenser is getting plenty of water or air. Make certain the cooling coils are defrosted and that power supply voltage is nominal when all systems are operating.

Should you have to contact Tenney about your refrigeration system, please jot down all the numbers on the compressor identification plate. Also, give us the serial number of the chamber. This will help us give you fast service on spare parts.

Before trouble-shooting the control system, get a copy of the electrical schematic. It is included with these instructions.

Open or short circuits, inoperative relays, blown fuses or open fail safe devices are most common malfunctions.

When shooting trouble, carefully trace one system at a time. Be systematic. Use a trouble light, buzzer or volt ohmeter. Don't carelessly tinker one circuit or system out of adjustmentment only to find the trouble somewhere else: Then, you'll have double trouble to repair and the job will be twice as difficult.

Use the X1 scale on an ohmeter when checking circuit continuity. Don't use X10, X100 or high or you'll sometimes get false readings.

TROUBLE SHOOTING

This section does not purport to be a complete and comprehensive trouble shooting guide for the serviceman. However, it attempts to help the operator locate the causes of possible troubles so that he can make simple repairs or adjustments himself. The information here should also help the user in localizing trouble so that he can better describe the malfunction when contacting the Tenney Service Department.

Refer to the appropriate electrical and refrigeration drawings when using these trouble-shooting suggestions.

Chamber completely dead - white light on:

1. Circuit breaker 1CB open.
2. Heat limiter HL open - red light is on.
3. Contactor 1CON not closed. Press the reset.

Conditioner fan dead:

4. Any trouble 1 through 3.
5. Fan motor shaft frozen. Try rotating fan by hand.
6. Defective fan motor. Feel for overheating.
7. Switching module 1SM-01 failing to conduct.

Buzzer buzzes when temperature is O.K:

8. Silence switch is thrown incorrectly. Transfer it.

Insufficient heat:

9. One of the control heaters is burned out.
10. Chamber door is ajar.
11. Temperature selection is too low. Try a higher temp as a test.

No heat:

12. Burned out heater elements, or open heat limiter.
13. Triac 1TIF-03 failing to conduct.
14. Open connection between triac and heater.
15. Open temperature sensor.
16. Short circuited setpoing pot circuit.
17. Open circuited switch SS.

Heater energizes constantly:

18. Triac 1TIF-03 has failed in conducting state.
19. Short circuited temperature sensor.
20. Open circuited setpoint pot.

High stage compressor won't run:

21. Motor overheated. Wait until cutout resets.
22. Triac 1TIF-06 not conducting.

23. Switching module 1SM-06 not conducting to triac.

24. Open connection between triac and motor.

25. Pressure cutout switch 4PS open. (on some chambers)

26. Switch SS on/off position.

Low stage compressor won't run:

27. Motor overheated. Wait until cutout resets.

28. Triac 1TIF-05 not conducting.

29. Switching module 1SM-05 not conducting to triac.

30. Low pressure cut-in switch 2PS open. This pressure switch responds to high-stage suction pressure. If the high stage is not running the low stage cannot run.

31. Hi-Lo pressure cutout switch 3PS open (on some chambers).

32. Switch SS off or defective.

Low stage runs, but little or no cooling:

33. Low stage is low on refrigerant. Have the system leak tested.

34. Full main solenoid valve 8SOL failing to open.

35. Artificial loading valve 14SOL stuck open full time.

36. Main cooling coil badly frosted.

Note: At site ambient temperature, if the chamber does not pull down substantially in temperature within 15 minutes, something is wrong. Turn the chamber off. Let it normalize and defrost. Then, try it again. If it still does not pull down to low temperature, shut it off and get technical help. A refrigeration system which does not cool properly should not be run for prolonged periods. It may have a leak and be low on refrigerant. Since the compressor depends upon cool returning refrigerant for cooling, it can be overheated when operated in an undercharged system.

Remember that the compressors have internal overloads with automatic reset; these are in addition to circuit breakers. Therefore, when a compressor cuts out, it must be given time to cool so that its internal protector has time to reset.

No humidification or insufficient humidification:

37. Lack of water flow to humidifier.

38. Chamber vent blocked.

39. Humidifier immersion heater open circuited.

40. Protective thermotat 2TAS open.

41. Water level too low in float bowl.

42. Triac 2TIF 12 failing to conduct.

43. Wet wick is dry or badly encrusted. A dry wet bulb reports falsely high humidity to the humidity controller. In response, the controller deenergizes the humidifier.

Low humidity cannot be attained:

44. Refrigeration system not running.

45. Load in chamber emits considerable moisture.

46. Solenoid valve 4SOL failing to feed dehumidification coil.

47. Module 2SM-14 is not conducting.

48. A malfunction is preventing the humidifier from shutting off.

PARTS IDENTIFICATION

Component parts are shown and identified on the drawings accompanying this manual. The bills of material indicate nomenclature and part numbers to be used in ordering replacement or spare parts.

PARTS REQUISITIONING

Identified by name and part number, parts can be ordered from Service Department, Tenney Engineering, Inc., 1090 Springfield Road, Union, New Jersey 07083. When parts are ordered, the serial number of the chamber should be given in addition to the nomenclature.

DANGER

THE MACHINERY COMPARTMENT HAS EXPOSED ELECTRICAL CONNECTIONS.

CAUTION

THIS IS NOT AN EXPLOSION-PROOF CHAMBER. It has modern, low mass, open wire heating elements to provide close temperature control. Due to their low mass, the heater wires can reach tempertures of 1,500/F, sufficient to ignite explosive mixtures of gases or vapors in the chamber. Because of the danger, DO NOT test any product in the chamber which is capable of generating combustible mixtures.

WARNING

DISCONNECT ALL ELECTRICAL POWER FROM THE FACILITY BEFORE SERVICING OR CLEANING THE CHAMBER INTERIOR.

TENNTROL II TECHNICAL INFORMATION

Data on the accompanying pages applies to TennTrol II, a control system for Tenney Environmental Chambers.

Temperature chambers, those without controlled humidity, are covered in the first 3 pages. Temperature/humidity chambers are covered in the final 5 pages.

The following drawings are included:

A007-1247-0000	Interface Board
A007-1238	Temperature Board
A007-1239	Display Board
A007-1240	Humidity Board

The first 3 drawings apply to both temperature and humidity chambers. The last drawing (1240) applies to humidity chambers only.

#

1.

TEMPERATURE CONTROL SYSTEM

WATLOW P/N TNNY-TMPC-0001

TENNTROL II
Temperature Only

GENERAL:

The Watlow TNNY-TMPC-0001 Temperature Control System is a custom wired assembly made for Tenney Engineering for use in controlling the temperature of an environmental chamber. It has integral to it a 3-1/2 digital L.E.D. display for reading temperature, temperature set point, and high-low alarm set points. Also included is the necessary logic required to provide automatic selection of the heat and cool functions.

SPECIFICATIONS:

A.C. SUPPLY: 115 volts, 50/60 Hz., ± 10%.

POWER CONSUMPTION: Less than 10 V.A.

SET POINT RANGE: -100°C to +199.9°C. Optional calibration: -100°C to +300°C with 1°C for L.S.D. Set by push-to-set mechanism and displayed on digital display.

SENSOR: Platinum temperature, sensor, 100 (ohms) at 0°C. Accepts two or three wire configuration. Connection to controller circuit board by screw terminals.

INDICATION RANGE: Displays digitally on 3-1/2 digit L.E.D. display. Accuracy ± 0.25% of calibrated temperature span plus or minus 1 L.S.D.

B.C.D. OUTPUT: Multiplexed B.C.D. signals for each digit and their associated digit select signals are available for external use. This connection is provided via a 12-pin ribbon cable header located on the display card. This output can drive a demultiplexer option P.C. assembly via ribbon cable for data presentation to printers, etc.

CONTROLLER: 2-mode heating and cooling temperature controller.

CONTROLLER ADJUSTMENTS: (on circuit P.C. board)

1. Proportional Band: Adjustable over the range of 5 to 50°C.
2. Auto Reset: Adjustable over the range of 0.5 to .05 repeats per minute.
3. Cycle Time: Adjusts automatically. 5 sec. minimum.

WINONA, MINNESOTA 55987 · 1265 EAST SANBORN STREET · PHONE 507 454-5300

TEMPERATURE CONTROL SYSTEM

WATLOW P/N TNNY-TMPC-0001

TENNTROL II
Temperature Only

SPECIFICATIONS: (Cont'd.)

4. Dead Band: Adjustable from 1% of proportional band to -25% of proportional band. (Heat and cooling overlaps and both can be operational at the same time.), -25% is overlap.

5. Balance: Allows actual temperature to equal set point for offsets in system. Range: ± 2°C minimum.

CONTROLLER OUTPUTS:

1. Heating Output: Will control Watlow solid state switching assemblies, such as A007-1074, A007-1108, or A007-1079, via an interface board which adapts the logic to different model Tenney chambers.

2. a) Cooling Output: Will control Watlow solid state switching assembly via an interface board.

   b) Compliment Cooling Output: Will control solid state switching assemblies via the interface board.

3. Deviation Output: Solder terminals. Will drive 500-0-500 µA meter for set-up purposes. Deviation range: ± 5°C.

4. Analog Signal: This output is a linearized output which is the signal conditioner output and can be used for driving a chart recorder, etc. Scaled for 2.5 millivolts per L.S.D. Output range -2.5 volts to 5.0 volts for temp. range -99.9°C to +199.9°C.

ALARM CIRCUIT:

Independent set points for high and low temperature. One common output is normally energized when operation is below the high and above the low alarm points. This output will de-energize if control operation moves into the alarm regions. This output is a relay with a Form-C contact rated 3 amps at 115v/230v, A.C. resistance load.

The alarm set points are screwdriver adjustable through the front panel. When the screwdriver is pushed in, the display will read the alarm set point. It is then adjusted by turning the screwdriver until the display reads the desired alarm point.

An alarm L.E.D. will light in display window when system is in an alarm condition.

TEMPERATURE CONTROL SYSTEM

WATLOW P/N TNNY-TMPC-0001

TENNTROL II
Temperature Only

SPECIFICATIONS: (Cont'd.)

TEMPERATURE CONTROL LOGIC:

1. Set Point Logic: Adjustable behind the panel on P.C. board. This logic output is on if selected temperature set point is below logic set point. This output controls a Watlow solid state switching assembly via an interface board.

2. % Cooling Turn-on: Adjustable behind the panel on P.C. board. Adjustment range: 5% to 20% of cooling proportional band. If % cooling exceeds set point value, the deviation output turns on.

3. % Heating Turn-off: Adjustable behind the panel on P.C. board. Adjustment range: 25% to 80% of heating proportional band. If % heating exceeds adjustment set point, the deviation output turns off.

The logic outputs will operate the Watlow solid state switching assemblies supplied Tenney Engineering via the interface board.

OUTPUT CONNECTIONS: All output connections for operating solid state switching assemblies via interface board are made by connecting ribbon cable plug into mating header on temperature control P.C. card.

FRONT PANEL: The front panel is sized and painted per Tenney Engineering's requirements.

It incorporates the front selector switch and cable assembly per Tenney Engineering's requirements.

% POWER DISPLAY: % power, -100 to +100; may be displayed for set-up purposes by operating slide switch on P.C. board. Accuracy: ± 5%.

AMBIENT OPERATING TEMPERATURE: 30°F to 130°F.

End of section on TennTrol II
Temperature Only

TEMPERATURE/HUMIDITY
CONTROL SYSTEM

WATLOW P/N TNNY-TRHC-0001
TENNTROL II
Temperature/Humidity

GENERAL:

The Watlow TNNY-TRHC-0001 Temperature/Humidity Control System is a custom wired assembly made for Tenney Engineering. It is used for controlling an environmental chamber. It has integral to it a 3-1/2 digit L.E.D. digital display for temperature and a 3-digit L.E.D. digital display for relative humidity. The temperature display reads actual temperature, set point temperature, high and low temperature alarm set points. The humidity display reads actual % relative humidity as well as the humidity set point. A three-position function switch is used for select off, temperature only, or temperature-humidity.

Included in this assembly is the necessary logic required to provide automatic selection of heat and cooling required to obtain the desired dry bulb temperature, as well as the logic to select the humidification or de-humidification required to obtain the humidity set point.

SPECIFICATIONS:

TEMPERATURE CONTROL SYSTEM:

A.C. SUPPLY: 115 volts, 50/60 Hz., ± 10%.

POWER CONSUMPTION: Less than 10 V.A.

SET POINT RANGE: -100.0°C to +199.9°C. Optional calibration: -100°C to +300°C with 1° L.S.D. set by push-to-set mechanism and displayed on digital display.

SENSOR: Platinum temperature sensor, 100 (ohms) at 0°C. Accepts two or three wire configuration.

INDICATION RANGE: Displays temperature on 3-1/2 digit L.E.D. display. Accuracy: ± 0.25% of calibrated temperature span, plus/minus 1 L.S.D.

B.C.D. OUTPUT: Multiplexed B.C.D. signals for each digit and their associated digit select signals are available for external use. This connection in provided via a 12-pin ribbon cable header located on temperature display card. This output can drive a de-multiplexer option P.C. assembly via a ribbon cable for data presentation to printers, etc.

TEMPERATURE CONTROLLER: 2-mode heating and cooling controller.

SPECIFICATIONS: (Cont'd.)

CONTROLLER ADJUSTMENTS: (on circuit P.C. board)

1. Proportional Band: Adjustable over the range of 5 to 50°C.

2. Auto Reset: Adjustable over the range of 0.5 to .05 repeats per minute.

3. Cycle Time: Adjusts automatically. 5 sec. minimum.

4. Dead Band: Adjustable from 1% of proportional band to -25% of the proportional band. (Heat and cooling can be adjusted for overlap.) -25% is overlap.

5. Balance: Allows actual temperature to equal set point value by adjusting out any system offsets. Range: ± 2°C minimum.

CONTROLLER OUTPUTS:

1. Heating Output: Will control Watlow solid state switch assembly via an interface board which adapts the system to different model Tenney chambers.

2. a) Cooling Output: This output will control a Watlow solid state switching assembly, Watlow P/N's A007-1074, A007-1079, or A007-1108, via the interface boards.

   b) Compliment Cooling Output: Simple compliment of cooling output.

3. Deviation Output: Solder terminals. Will drive 500-0-500 micro-ampere meter for set-up purposes. Range: ± 5°C for ± 500 µA.

4. Analog Signal: This output is a linearized output voltage and can be used for driving a chart recorder, etc. Scaled 2.5 millivolts per L.S.D. Output range - 2.5 volts to 5.0 volts for the temp. range of -99.9°C to +199.9°C.

TEMPERATURE ALARM CIRCUIT:

Independent set points for high and low temperature. One common output is normally energized when system operation is below the high and above the low alarm set points. This output will de-energize if system operation moves into the alarm regions. This output is a relay with a Form-C contact rated 3 amps at 115/230V A.C., resistive load.

SPECIFICATIONS: (Cont'd.)

The alarm set points are screwdriver adjustable through the front panel. When the screwdriver is pushed in, the digital display will read the alarm set point to be adjusted. The screwdriver is then rotated until the display reads the desired alarm point.

An alarm L.E.D. will light on the control panel when the system is in an alarm condition.

TEMPERATURE CONTROL LOGIC:

1. Set Point Logic: Adjustable behind the panel on the P.C. board. This logic output is energized if the selected temperature set point is below the logic set point.

2. % Cooling Turn-on: Adjustable behind the panel on the P.C. board. Adjustment range: 5% to 20% of cooling proportional band. If % cooling exceeds set point value, the deviation output energizes.

3. % Heating Turn-Off: Adjustable behind the panel on the P.C. board. Adjustment range: 25% to 80% of heating proportional band. If % heating exceeds adjustment set point, the deviation output will de-energize if energized.

4. The outputs all connect to the interface board.

HUMIDITY CONTROL SYSTEM:

A.C. SUPPLY: 115 volts, 50/60 Hz., ± 10%.

POWER CONSUMPTION: Less than 10 V.A.

SET POINT RANGE: 0 to 99.9% R.H.

SENSOR: Differential connect of wet and dry bulb thermocouples plus thermistor sensor for dry bulb temperature measurement.

INDICATION RANGE: Display digital, 3 digits, accuracy per Watlow standard % R.H. signal conditioner. Range: 00.0 to 99.9.

B.C.D. OUTPUT: Multiplexed B.C.D. signals for each digit and their associated digital select signals are available for external use. This connection is provided via a 12-pin ribbon cable header located on the P.C. card. This output can drive a de-multiplexer option P.C. assembly via ribbon cable for data presentation to printers, etc. This P.C. assembly is Watlow P/N A007-XXXX-XXXX.

TEMPERATURE/HUMIDITY
CONTROL SYSTEM

WATLOW P/N TNNY-TRHC-0001
TENNTROL II
Temperature/Humidity

SPECIFICATIONS: (Cont'd.)

HUMIDITY CONTROLLER: 2 mode, humidify and de-humidify controller.

CONTROLLER ADJUSTMENTS: (on circuit P.C. board)

1. Proportional Band: Adjustable over the range of 8 to 80% R.H.
2. Auto Reset: Adjustable over the range of 0.5 to 0.05 repeats per minute.
3. Cycle Time: Adjusts automatically.
4. Dead Band: Adjustable from 1% of proportional band to -25% of proportional band. -25% is the overlap.
5. Balance: Allows indicated actual % R.H. to equal set point value by adjusting out any system offsets. Range: ± 5% R.H.

CONTROLLER OUTPUTS:

1. Humidify Output.
2. De-humidify Output: Both of these outputs will control a Watlow solid state switching assembly, via the interface board.
3. Deviation Output: Solder terminals. Output will drive 500-0-500 micro-ampere for set-up purposes. Range: ± 25% R.H. for ± 500 μA.
4. Analog Signal: This output can be used to drive external chart recorder, etc. Scaled 0 to 5 volts for 0 to 99.9% R.H.

   The analog output will be disabled when front panel switch is in temperature only position.

HUMIDITY CONTROL LOGIC: (Deviation Type)

1. % De-humidify Turn-On: Adjustable behind the panel on P.C. board. Adjustment range: 5% to 20% of de-humidify proportional band. If % de-humidify exceeds set point value, the output will energize.
2. % Humidify Turn-Off: Adjustable behind the panel on the P.C. board. Adjustment range: 25% to 80% of the humidify proportional band. If % humidify exceeds adjustment set point value, the previous output, if energized during de-humidification, will de-energize.

TEMPERATURE/HUMIDITY
CONTROL SYSTEM

WATLOW P/N TNNY-TRHC-0001
TENNTROL II
Temperature/Humidity

SPECIFICATIONS: (Cont'd.)

The logic output will control the Watlow solid state switching assembly via the interface board.

OUTPUT CONNECTIONS:

All output connections are made by connecting a ribbon cable plug into mating headers on P.C. assemblies.

% POWER DISPLAY:

% power: -100 to +100 will be displayed for set-up purposes on the temperature and humidity controls. This is accomplished by operating a switch on the respective board and observing the % power on the respective digital display. Accuracy ± 5%.

FRONT PANEL:

The front panel is sized and painted per Tenney Engineering's requirements.

It will incorporate the front selector switch, cable assembly per requirements.

AMBIENT OPERATING TEMPERATURE:

30 to 130°F.

End of section on TennTrol II
Temperature/Humidity

CALIBRATION PROCEDURES

TENNTROL II

The first section of this instruction covers TennTrol II temperature boards. The second section covers humidity boards. If yours is a temperature-only chamber, ignore the material applying to humidity boards.

TNNY-TMPC-000X
A007-1238-0000
CALIBRATION PROCEDURE

TENNTROL II TEMP BOARD

CALIBRATION

Equipment Needed:

1. 1K decade box.
2. D.V.M.

Set-Up:

1. Connect D.V.M. to S/C out and common. See Figure 1.
2. Place five-pole power circuit breaker in OFF position.
3. Determine if narrow range (-100 to +199.9°C) or wide range (-100 to +300°C) by noting if 0.1's°C (narrow range) are displayed or not (wide range).

Procedure:

1. Hook decade box to S1-S2-S3 on unit. Use two wires to connect S2 and S3 to the decade box on the same terminal. See Figure 1.
2. Set display select switch to norm. Set selector switch to temp. Set decade box to 100.00 ohm, adjust 'SC LO' pot for .000V on D.V.M. Display should indicate 000 ±1LSD (least significant digit).
3. Set decade box to 177.0 ohm (213.8 ohm opt.), adjust 'SC HI' pot for D.V.M. reading of 5.00 VDC (7.50 VDC option). Adjust 'HI' pot on display board for a display of 199.9°C (option 300°C).
4. Repeat steps 2 and 3 until proper readings are obtained.
5. Set decade box to 139.1 ohm (158.2 ohm opt.). Display should read 100°C (150°C opt.) ±1LSD. D.V.M. should read 2.50 VDC (3.75 VDC opt.).

Note: The COOL and HEAT adjustments may interact so always check both when a change to either is made.

4. Deadband:

Can be used to overlap heating and cooling, i.e., heat and cool proportioning at the same time. Normally, set full CCW, providing a deadband between heating and cooling proportioning action.

5. Proportional Band: (PB)

Minimum P.B. is full counterclockwise, turn pot clockwise to increase P.B.

6. Reset:

Fastest Reset is full counterclockwise, turn pot clockwise to increase the Reset time.

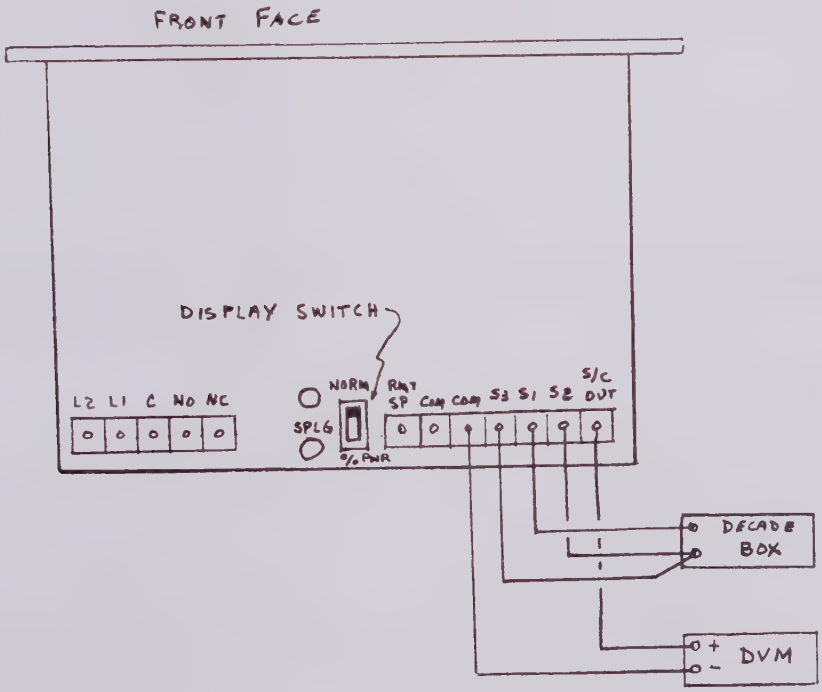


FIGURE 1

TNNY-TRHC-0001
A007-1240-0001
TENNTROL II

HUMIDITY BOARD

Equipment Needed:

1. D.V.M.
2. MV source.
3. 100K Decade Box.

Set-Up:

1. Hook D.V.M. to E out and common except for Test Procedure 1, See Figure 1.

2. Hook mV source to mV source terminals.

3. Hook decade box to sensor terminals.

Test Procedure:

1. Set selector switch to humidity. Set display select (SW55) to NORM. Set decade box to 76.420K. Set mV source to OFF and jumpers S1 and S2. Adjust Lo pot for 0.000V on D.V.M. reading between S4 (+) and COM. Set 100% max. pot full C.W.

2. Set decade box to 45.494K. Remove jumper and set Mv source to .622 mV. Adjust 10% pot for .500 VDC, ±.002 on D.V.M. (E out and com).

3. Set mV source to OFF and jumpers S1 and S2. Adjust 100% pot for 5.000 VDC on D.V.M. Adjust hi pot for 100.00 on display.

4. Repeat steps 2 and 3 as necessary to obtain proper results.

5. Following step 3, adjust 100% max. pot C.C.W. to 99 then turn pot C.W. until display changes back to 100.0.

6. Remove jumper and set mV source to .316 mV. Display should indicate 50.0, ±1.0.

6. Decade box should be set for 139.1 ohm and set point adjusted for 100°C (option would set decade for 158.2 ohm, and set point for 150°C). Set Display Switch to % PWR, P.B. and D.B. potentiometers full C.C.W., and Reset potentiometer full C.W. Adjust BAL potentiometer for 000 on display, ±1LSD (±10LSD for option).

Operator Settings:

1. Set Point Logic: (SP LOGIC)

   Controls the switchover between partial and full cooling. Usually adjusted for a switchover set point of 19°C. To set, put Display Switch in mid-position (SPLG), and adjust SP LOGIC potentiometer until display reads the desired value.

2. Percent Cooling: (COOL)

   Controls compressor turn on as a function of the percent of cooling being called for and is usually adjusted to turn the compressor on at -10.0% cooling.

   To change, set the decade box for 139.1 ohm and adjust the set point to agree with the measurement value (100°C nominal). Put the Display Switch in the % PWR position, P.B. and D.B. potentiometers full C.C.W., and Reset potentiometer full C.W. Slowly decrease the set point while observing the LED for output 1SM-06. When output 6 comes ON, check % PWR on the display. To change the setting for compressor TURN ON, make an adjustment to the COOL potentiometer (CW increases). Then manipulate the set point pot to turn output 6 OFF, followed by slowly decreasing the set point and observing the turn ON point for output 6. Continue with this procedure until the desired effect is obtained.

3. Percent Heating: (HEAT)

   Controls compressor TURN OFF as a function of the percent of heat being called for, and is usually adjusted to turn the compressor off at 50% heating. To change, set the decade box for 139.1 ohm, and adjust the set point to agree with the measurement value (100°C nominal). Put the Display Switch in the % PWR position, P.B. and D.B. potentiometers full C.C.W., and Reset potentiometer full C.W. Slowly increase the set point while observing the LED for output 1SM-06. When output 6 goes OFF, check % PWR on the display. If it is desired to change the setting for compressor TURN OFF, make an adjustment to the HEAT potentiometer (CCW increases). Then manipulate the set point to turn output 6 ON followed by slowly increasing the set point and observing the turn OFF point for output 6. Continue with this procedure until the desired effect is obtained.

7. Set D.B. and P.B. pots full C.C.W., and reset full C.W. Adjust set point to match the display. Set Display Switch to % PWR. Adjust BAL pot for 00.0, ±1.0 on the display.

Operator Settings:

1. Percent Dehumidify: (DEHUM)

Controls compressor TURN ON as a function of the percent of dehumidification being called for, and is usually adjusted to turn the compressor on at -10% dehumidify. To change, set the mV source to 0.316 mV, and adjust the set point to agree with the measurement value (50% nominal), and set D.B. and P.B. pots full C.C.W., and reset full C.W. Put the Display Switch in the % PWR position and slowly decrease the set point while observing the LED for output 1SM-06. When ouput 6 comes ON, check % PWR on the display. To change the compressor TURN ON setting, make an adjustment to the DEHUM potentiometer (C.W. increases). Then manipulate the set point pot to turn output 6 OFF, followed by slowly decreasing the set point and observing the TURN ON point for output 6. Continue with this procedure until the desired effect is obtained.

2. Percent Humidify: (HUM)

Controls compressor TURN OFF as a function of the percent of humidification being called for, and is usually adjusted to turn the compressor off at 50% humidify. To change, set the mV source to 0.316 mV, and adjust the set point to agree with the measurement value (50% nominal), and set D.B. and P.B. pots full C.C.W., and reset full C.W.

Put the Display Switch in the % PWR position, and slowly increase the set point while observing the LED for output 1SM-06. When output 6 goes OFF, check % PWR on the display. To change the compressor TURN OFF setting, make an adjustment to the HUM potentiometer (C.C.W. increases). Then manipulate the set point pot to turn output 6 ON , followed by slowly increasing the set point and observing the TURN OFF point for output 6. Continue with this procedure until the desired effect is obtained.

Note: The DEHUM and HUM adjustments may interact so always check both when a change to either is made.

3. Deadband:

Can be used to overlap humidify and dehumidify, i.e., humidify and dehumidify proportioning at the same time. Normally, set full C.C.W. providing a deadband between humidifying and dehumidifying proportioning.

4. Proportional Band: (PB)

Minimum P.B. is full counterclockwise; turn pot clockwise to increase P.B.

5. Reset:

Fastest RESET is full counterclockwise; turn pot clockwise to increase the RESET time.

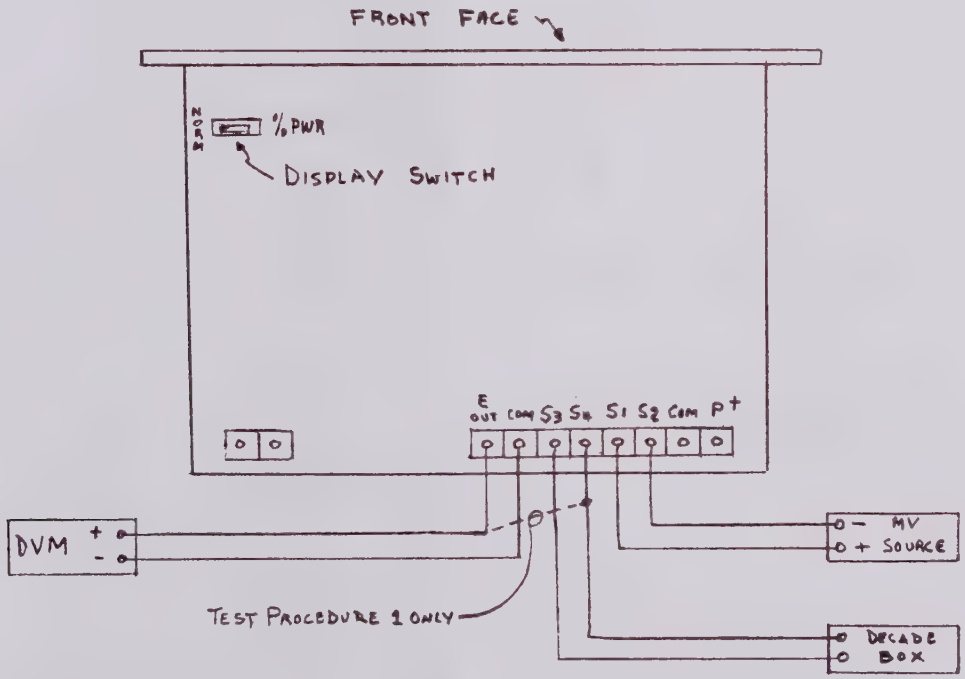
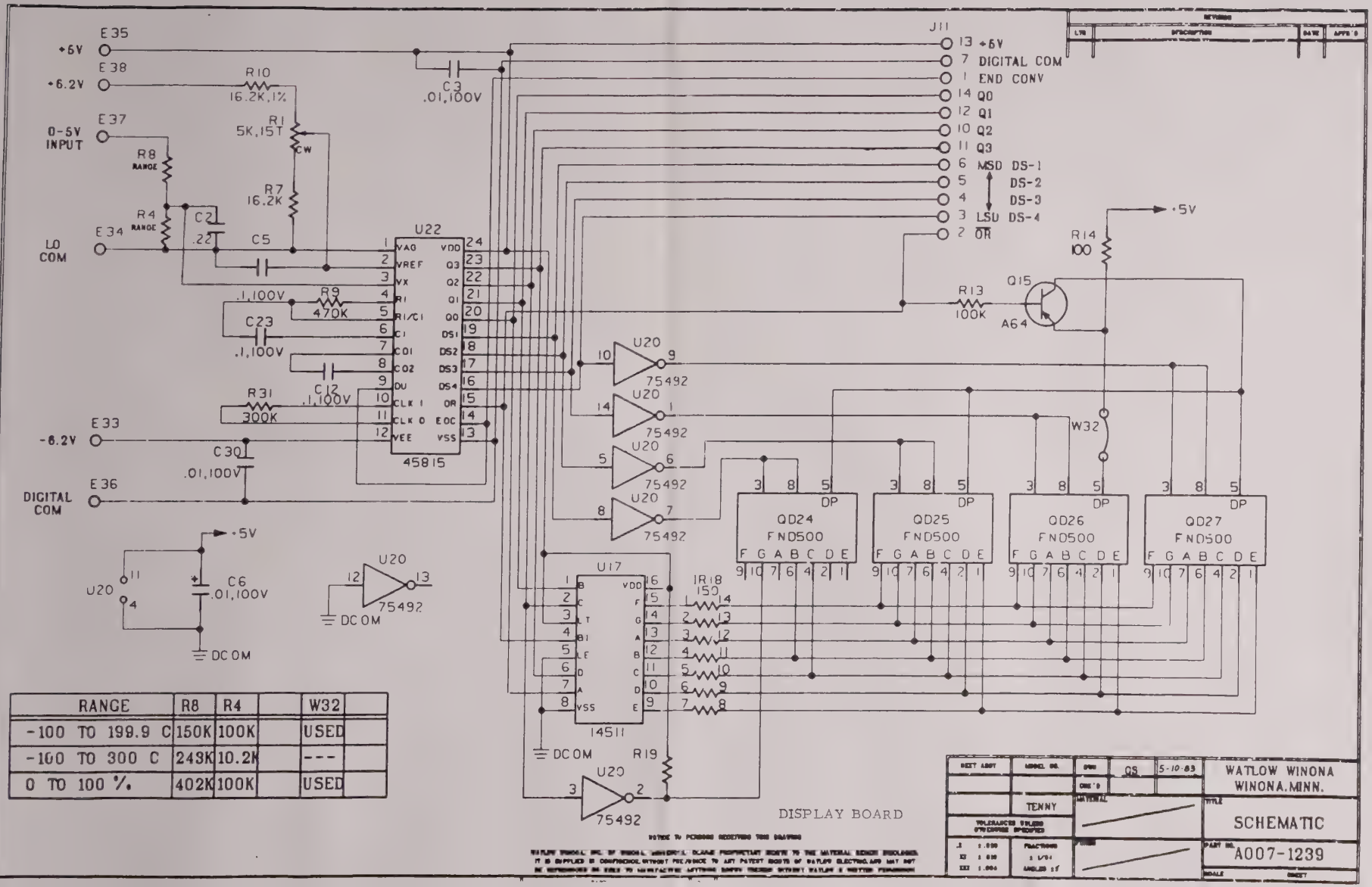


FIGURE 1



RANGE	R8	R4		W32	
-100 TO 199.9 C	150K	100K		USED	
-100 TO 300 C	243K	10.2K		---	
0 TO 100 %	402K	100K		USED	

DISPLAY BOARD

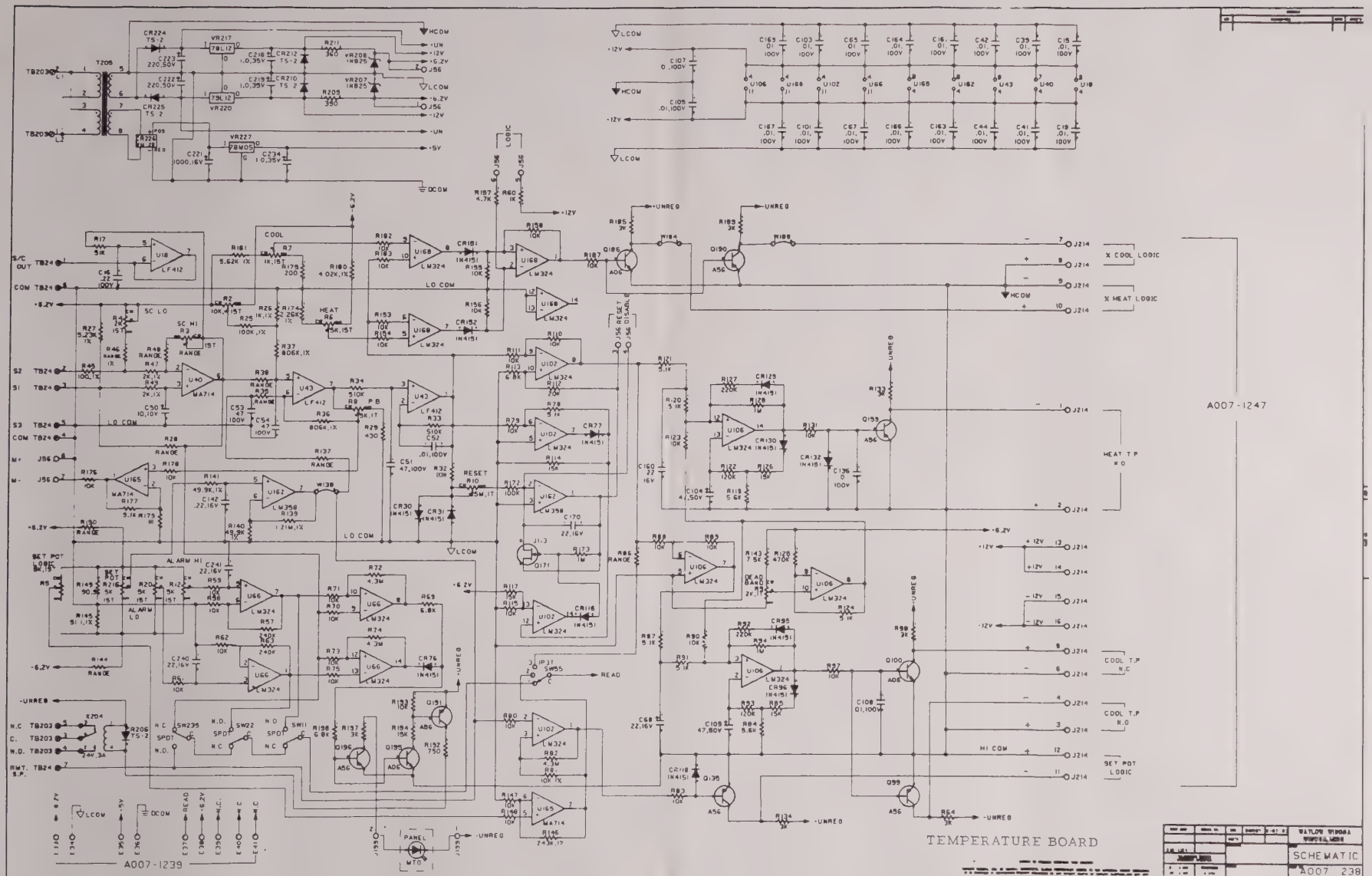
NEXT ASSY	MODEL NO.	DRN	QS	5-10-83
		CHK'D		
TENNY		MATERIAL		
TOLERANCES UNLESS OTHERWISE SPECIFIED		FINISH		
.X ± .030	FRACTIONS ± 1/64			
.XX ± .010	ANGLES ± 1°			
.XXX ± .004				

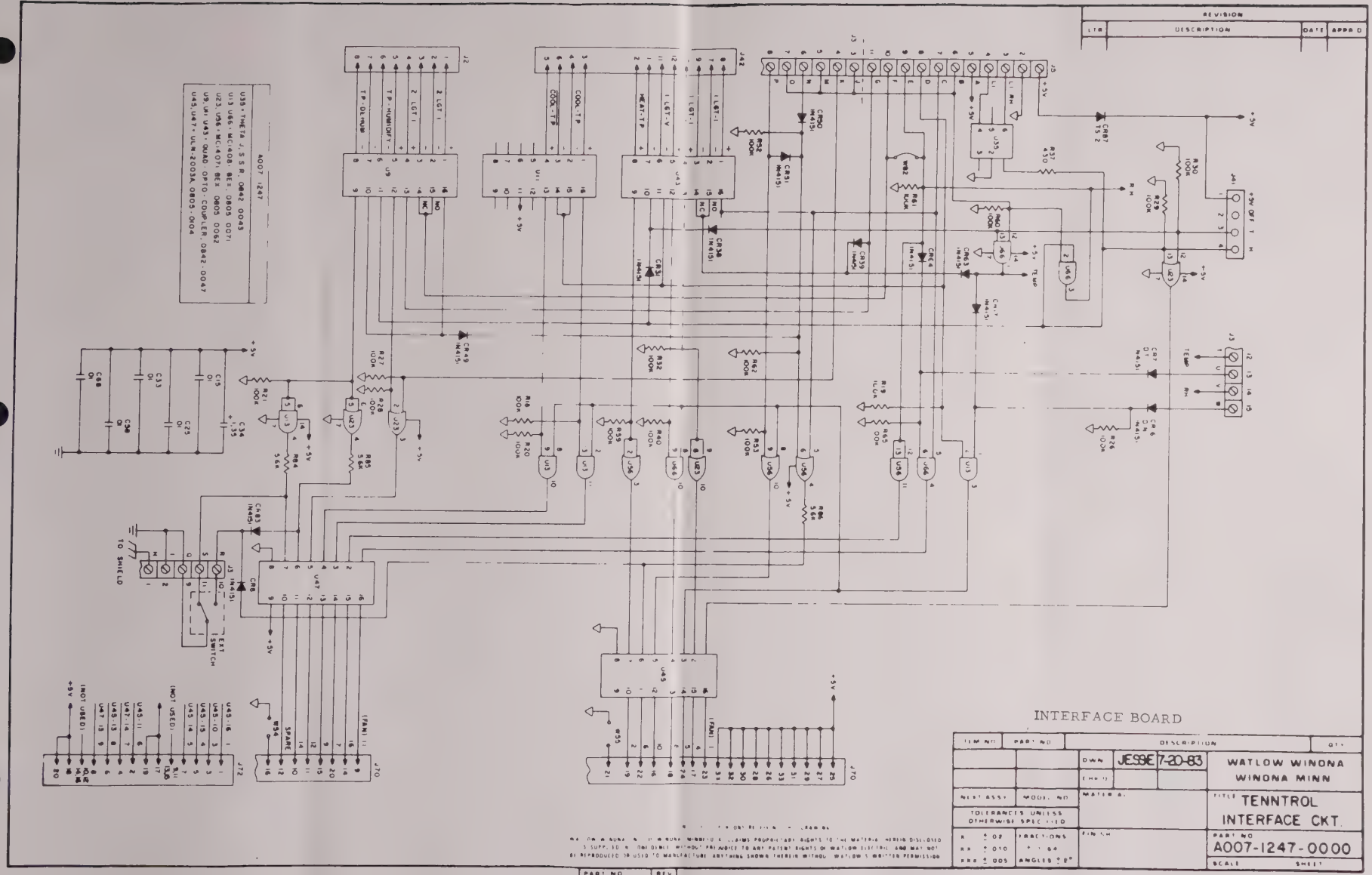
WATLOW WINONA
WINONA, MINN.

TITLE: SCHEMATIC

PART NO. A007-1239

SCALE | SHEET


TEMPERATURE BOARD
A007-1247
A007-1239
SCHEMATIC
A007 238
X COOL LOGIC
X HEAT LOGIC
HEAT T.P N.O
COOL T.P N.C
COOL T.P N.O
SET POT LOGIC
HI COM
LO COM
READ
PANEL
+UNREG
-UNREG
+12V
-12V
+6.2V
-6.2V
-5V
+5V
LCOM
HCOM
DCOM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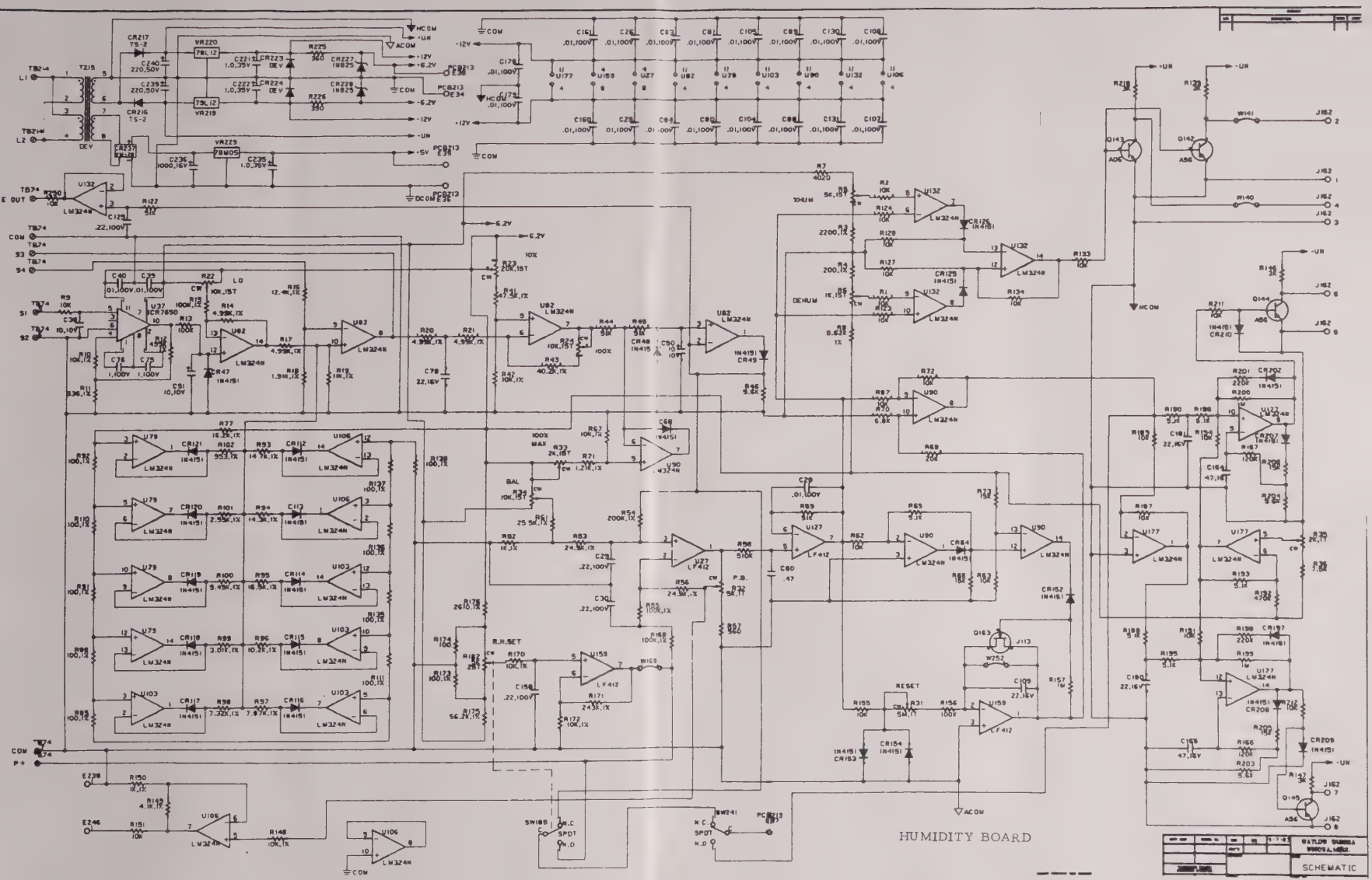
LTR
DESCRIPTION
DATE
APPR'D
A007 1247
U35-THETA J.S.S.R. 0842 0043
U13 U65-MC1408L BEX 0805 0071
U23 U56-MC1401 BEX 0805 0062
U9 U41 U43-QUAD OPTO-COUPLER 0842-0047
U45 U47-ULN-2003A 0805-0104
INTERFACE BOARD
TENNTROL
INTERFACE CKT.
A007-1247-0000
WATLOW WINONA
WINONA MINN
JESSE 7-20-83
TO SHIELD
TEST SWITCH
SPARE
(FAN) 11
(NOT USED)
+5V
+5V OFF T H
TEMP
R H


HUMIDITY BOARD
SCHEMATIC
A007-1240

TENNEY RELATIVE HUMIDITY TABLE IN DEGREES FAHRENHEIT

DRY BULB DEG. F.	DIFFERENCE BETWEEN READINGS OF WET AND DRY BULBS IN DEGREES FAHRENHEIT																																		DRY BULB DEG. F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	65	70	
30	89	78	67	56	46	36	26	16	6	0	0																										30
35	91	81	72	63	54	45	36	27	19	10	2	0																									35
40	92	83	75	68	60	52	45	37	29	22	15	7	0	0																							40
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6	0	0																					45
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5	0	0																			50
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	14	9	5	0	0																	55
60	94	88	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	0																60
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	5	0															65
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	12	6	0	0													70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0												75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0											80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0									85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0								90
95	96	92	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0							95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4							100
102	96	93	89	86	83	80	77	74	71	69	65	62	59	57	54	52	49	47	45	43	38	34	30	26	23	20	16	13	10	6							102
104	96	93	90	86	83	80	77	74	71	69	65	63	60	58	55	52	50	48	46	43	39	35	31	27	23	21	18	15	12	8	1						104
106	96	93	90	87	83	80	77	74	72	69	66	63	60	58	56	53	51	48	46	55	40	36	32	28	24	21	19	16	13	10	3						106
108	96	93	90	87	84	81	78	75	72	70	66	64	61	59	56	54	51	49	47	45	41	37	33	29	26	22	19	17	14	11	5						108
110	96	93	90	87	84	81	78	75	72	70	67	64	62	60	57	55	52	50	48	46	41	37	34	30	27	23	20	17	15	12	6						110
112	96	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	53	51	49	47	42	38	35	31	28	24	21	18	15	13	7	1					112
114	97	93	90	87	84	81	78	75	73	71	68	65	63	61	58	56	53	51	49	47	43	39	35	32	28	25	22	19	16	13	8	3					114
116	97	93	90	88	84	82	79	76	74	71	68	66	63	61	59	56	54	52	50	48	44	40	36	33	29	26	24	20	17	14	9	4					116
118	97	93	91	88	85	82	79	76	74	71	68	66	64	62	59	57	54	53	51	49	44	41	37	34	30	27	24	21	19	15	10	5					118
120	97	94	91	88	85	82	79	77	74	72	69	66	64	62	60	57	55	53	51	49	45	41	38	34	31	28	25	22	19	16	10	7	2				120
122	97	94	91	88	86	82	79	77	75	72	69	67	65	63	60	58	56	54	52	50	46	42	38	35	32	29	26	23	20	17	12	8	2				122
124	97	94	91	88	85	83	80	77	75	72	70	67	65	63	61	58	56	54	52	51	46	43	39	36	33	29	27	24	21	18	13	8	3				124
126	97	94	91	88	86	83	80	78	75	73	70	68	65	64	61	59	57	55	53	51	47	43	40	37	33	30	28	25	22	19	14	9	5	0			126
128	97	94	91	89	86	83	80	78	76	73	71	68	66	64	61	59	57	55	53	52	47	44	40	37	34	31	28	25	23	20	15	10	6	2			128
130	97	94	91	89	86	83	80	78	76	73	71	68	66	64	62	60	58	56	54	52	48	44	41	38	35	32	29	26	24	21	15	10	7	3			130
132	97	94	92	89	86	83	81	78	76	74	71	69	67	65	62	60	58	56	54	53	49	45	42	39	35	32	30	27	24	22	16	11	8	3			132
134	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	59	57	55	53	49	46	42	39	36	33	31	28	25	23	17	12	8	4	0		134
136	97	94	92	89	86	84	81	79	77	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	37	34	31	28	26	24	18	13	9	5	2		136
138	97	94	92	89	86	84	81	79	77	74	72	70	68	66	63	62	60	58	56	54	50	47	43	40	37	35	32	29	27	24	19	14	10	6	2		138
140	97	94	92	89	87	84	81	79	77	75	72	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	33	30	27	25	19	14	10	7	3		140
142	97	94	92	89	87	84	82	80	77	75	73	70	68	66	64	62	60	58	57	55	51	48	44	42	39	36	33	30	28	26	20	15	11	8	4	1	142
144	97	95	92	89	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	26	21	16	11	8	5	2	144
146	97	95	92	90	87	85	82	80	78	75	73	71	69	67	65	63	61	59	57	56	52	49	45	43	40	37	35	32	29	27	21	17	12	9	6	2	146
148	97	95	92	90	87	85	82	80	78	76	73	71	69	67	65	63	61	60	58	56	53	49	46	43	40	38	35	32	30	28	22	17	13	10	6	3	148
150	98	95	92	90	87	85	82	80	78	76	74	72	70	68	66	64	62	60	58	57	53	49	46	43	41	38	36	33	30	28	23	18	13	10	7	4	150
152	98	95	93	90	88	85	83	81	79	76	74	72	70	68	66	64	62	60	59	57	53	50	47	44	41	39	36	33	31	29	23	19	14	10	8	5	152
154	98	95	93	90	88	85	83	81	79	77	74	72	70	68	66	65	63	61	59	57	54	50	47	44	42	39	37	34	32	29	24	19	15	11	8	5	154
156	98	95	93	90	88	85	83	81	79	77	74	72	71	69	67	65	63	61	59	58	54	51	48	45	42	40	37	34	32	30	24	20	15	11	9	6	156
158	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	63	61	60	58	55	51	48	45	43	40	38	35	33	30	25	20	16	12	10	7	158
160	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	64	62	60	58	55	52	49	46	43	41	38	35	33	31	25	21	17	13	10	7	160
162	98	95	93	90	88	86	84	82	80	77	75	73	71	69	68	66	64	62	60	59	55	52	49	46	44	41	39	36	34	31	26	22	17	13	11	8	162
164	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	36	34	32	26	22	18	14	11	9	164
166	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	66	65	63	61	59	56	53	50	47	44	42	39	37	35	32	27	23	18	14	12	9	166
168	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	67	65	63	61	60	56	53	50	47	45	42	40	37	35	33	28	23	19	15	12	9	168
170	98	95	93	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	51	48	45	43	40	38	35	33	28	24	19	15	13	10	170
172	98	95	93	91	89	86	84	82	81	78	76	74	73	71	69	67	66	64	62	60	57	54	51	48	46	43	41	38	36	34	28	24	20	16	13	10	172
174	98	95	93	91	89	87	84	83	81	78	76	75	73	71	69	67	66	64	62	61	57	54	51	49	46	43	41	39	36	34	29	24	20	16	13	10	174
176	98	96	94	91	89	87	85	83	81	79	77	75	73	71	70	68	66	64	63	61	58	55	52	49	46	44	42	39	37	35	29	25	21	17	14	10	176
178	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	49	47	44	42	39	37	35	30	25	21	17	14	11	178
180	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	67	65	63	62	58	55	52	50	47	45	42	40	38	35	30	26	22	18	15	11	180
182	98	96	94	91	89	87	85	83	81	79	77	75	74	72	70	68	67	65	63	62	59	56	53	50	48	45	43	40	38	36	31	26	22	18	15	12	182
184	98	96	94	92	89	87	85	83	82	79	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	16	12	184
186	98	96	94	92	90	87	85	83	82	80	78	76	74	72	71	69	67	66	64	62	59	56	53	51	48	46	43	41	39	37	32	27	23	19	17	13	186
188	98	96	94	92	90	87	85	84	82	80	78	76	74	73	71	69	68	66	64	63	59	57	54	51	49	46	44	41	39	37	32	27	23	20	18	13	188
190	98	96	94	92	90	88	85	84	82	80	78	76	75	73	71	69	68	66	65	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	18	14	190
200	98	96	94	92	90	88	86	84	82	80	79	77	75	74	72	70	69	67	66	64	61	58	55	53	51	48	46	43	41	39	34	30	26	22	19	16	200
205	98	96	94	92	90	88	86	84	83	81	79	77	76	74	72	71	69	68	66	65	62	59	56	54	51	49	46	44	42	40	35	31	27	23	20	17	205
210	98	96	94	92	90	88	87	85	83	81	80	78	76	75	73	71	70	68	67	65	62	60	57	54	52	49	47	45	43	41	36	32	28	24	21	18	210

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TENNEY RELATIVE HUMIDITY TABLE IN DEGREES CENTIGRADE

DRY BULB DEG. C	DIFFERENCE BETWEEN READINGS OF WET AND DRY BULBS IN DEGREES CENTIGRADE																														DRY BULB DEG. C
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32	34	36	38	40	
2	92	83	75	67	59	52	43	36	27	20																							2
4	93	85	77	70	63	56	48	41	34	28	15																						4
6	94	87	80	73	66	60	54	47	41	35	23	11																					6
8	94	87	81	74	68	62	56	50	45	39	28	17																					8
10	94	88	82	76	71	65	60	54	49	44	34	23	14																				10
12	94	89	84	78	73	68	63	58	53	48	38	30	21	4																			12
14	95	90	84	79	74	69	65	60	55	51	41	33	24	16	10																		14
16	95	90	85	81	76	71	67	62	58	54	45	37	29	21	14	7																	16
18	95	90	86	82	78	73	69	65	61	57	49	42	35	27	20	13	6																18
20	96	91	87	82	78	74	70	66	62	58	51	44	36	30	23	17	11																20
22	96	92	87	83	79	75	72	68	64	60	53	46	40	34	27	21	16	11															22
24	96	92	88	85	81	77	74	70	66	63	56	49	43	37	31	26	21	14	10														24
26	96	92	89	85	81	77	74	71	67	64	57	51	45	39	34	28	23	18	13														26
28	96	92	89	85	82	78	75	72	68	65	59	53	47	42	37	31	26	21	17	13													28
30	96	93	89	86	82	79	76	73	70	67	61	55	50	44	39	35	30	24	20	16	12												30
32	96	93	90	86	83	80	77	74	71	68	62	56	51	46	41	36	32	27	23	19	15												32
34	97	93	90	87	84	81	77	74	71	69	63	58	53	48	43	38	34	30	26	22	18	10											34
36	97	93	90	87	84	81	78	75	72	70	64	59	54	50	45	41	36	32	28	24	21	13											36
38	97	94	90	87	84	81	79	76	73	70	65	60	56	51	46	42	38	34	30	26	23	16	10										38
40	97	94	91	88	85	82	79	76	74	71	66	61	57	52	48	44	40	36	32	29	25	19	13										40
42	97	94	91	88	85	82	80	77	74	72	67	62	58	53	49	45	41	38	34	31	27	21	15										42
44	97	94	91	88	86	83	80	77	75	73	68	63	59	54	50	47	43	39	36	32	29	23	17	12									44
46	97	94	91	89	86	83	81	78	76	73	68	64	60	55	52	48	44	41	37	34	31	25	19	14									46
48	97	94	92	89	86	84	81	78	76	74	69	65	61	56	53	49	45	42	39	35	33	27	21	16	12								48
50	97	94	92	89	87	84	82	79	77	75	70	65	62	57	54	50	47	43	40	37	34	28	23	18	14								50
52	97	94	92	89	87	84	82	79	77	75	70	66	62	58	55	51	48	44	41	38	35	30	25	20	16	11							52
54	97	95	92	90	87	85	82	80	78	76	71	67	63	59	56	52	49	45	42	39	36	31	26	21	17	13							54
56	97	95	92	90	87	85	83	80	78	76	72	68	64	60	57	53	50	46	43	40	38	32	27	23	19	15	11						56
58	97	95	93	90	88	85	83	80	79	77	72	68	64	61	57	54	51	47	44	42	39	33	29	24	20	16	12						58
60	98	95	93	90	88	86	83	81	79	77	73	69	65	62	58	55	52	48	45	43	40	35	30	26	21	18	14	11					60
62	98	95	93	91	88	86	84	81	79	78	73	69	66	62	59	56	53	49	46	43	41	36	31	27	23	19	15	12					62
64	98	95	93	91	88	86	84	82	80	78	74	70	66	63	59	56	53	50	47	44	42	37	32	28	24	20	17	13					64
66	98	95	93	91	89	86	84	82	80	78	74	70	67	64	60	57	54	51	48	45	43	38	33	29	25	21	18	15	12				66
68	98	95	93	91	89	87	85	82	81	79	75	71	67	64	61	58	55	52	49	46	44	39	34	30	26	22	19	16	13				68
70	98	96	93	91	89	87	85	83	81	79	75	71	68	65	61	58	55	52	50	47	44	40	35	31	27	23	20	17	14	11			70
72	98	96	94	92	89	87	85	83	81	80	76	72	69	65	62	59	56	53	50	48	45	40	36	32	28	24	21	18	15	12			72
74	98	96	94	92	90	87	85	83	82	80	76	72	69	66	63	60	57	54	51	48	46	41	37	33	29	25	22	19	16	13	11		74
76	98	96	94	92	90	88	86	84	82	80	76	73	70	66	63	60	57	54	52	49	47	42	38	34	30	26	23	20	17	14	12		76
78	98	96	94	92	90	88	86	84	82	81	77	73	70	67	64	61	58	55	52	50	47	43	38	34	30	27	24	21	18	15	13	10	78
80	98	96	94	92	90	88	86	84	83	81	77	74	71	67	64	61	58	56	53	50	48	43	39	35	31	28	24	22	19	16	14	11	80
82	98	96	94	92	90	88	86	84	83	81	77	74	71	68	65	62	59	56	54	51	49	44	40	36	32	29	25	22	20	17	15	12	10	82
84	98	96	94	92	90	88	86	84	83	81	78	74	71	68	65	62	59	57	54	52	49	45	40	37	33	29	26	23	20	18	16	13	11	84
86	98	96	94	92	91	89	87	85	83	82	78	75	72	69	66	63	60	57	55	52	50	45	41	37	34	30	27	24	21	19	16	14	12	86
88	98	96	95	93	91	89	87	85	83	82	78	75	72	69	66	63	60	58	55	53	51	46	42	38	34	31	28	25	22	19	17	15	13	88
90	98	97	95	93	91	89	87	85	84	82	79	76	73	69	67	64	61	58	56	53	51	47	42	39	35	32	28	26	23	20	18	16	14	90
92	98	97	95	93	91	89	87	86	84	82	79	76	73	70	67	64	61	59	56	54	52	47	43	39	36	32	29	26	24	21	19	16	14	92
94	99	97	95	93	91	89	88	86	84	83	79	76	73	70	67	65	62	59	57	54	52	48	44	40	36	33	30	27	24	22	19	17	15	94
96	99	97	95	93	91	90	88	86	84	83	80	76	74	70	68	65	62	60	57	55	53	48	44	41	37	34	31	28	25	22	20	18	16	96
98	99	97	95	93	92	90	88	86	85	83	80	77	74	71	68	65	63	60	58	55	53	49	45	41	38	34	31	28	26	23	21	19	16	98
100	99	97	95	93	92	90	88	86	85	83	80	77	74	71	68	65	63	60	58	56	54	49	45	42	38	35	32	29	26	24	22	19	17	100

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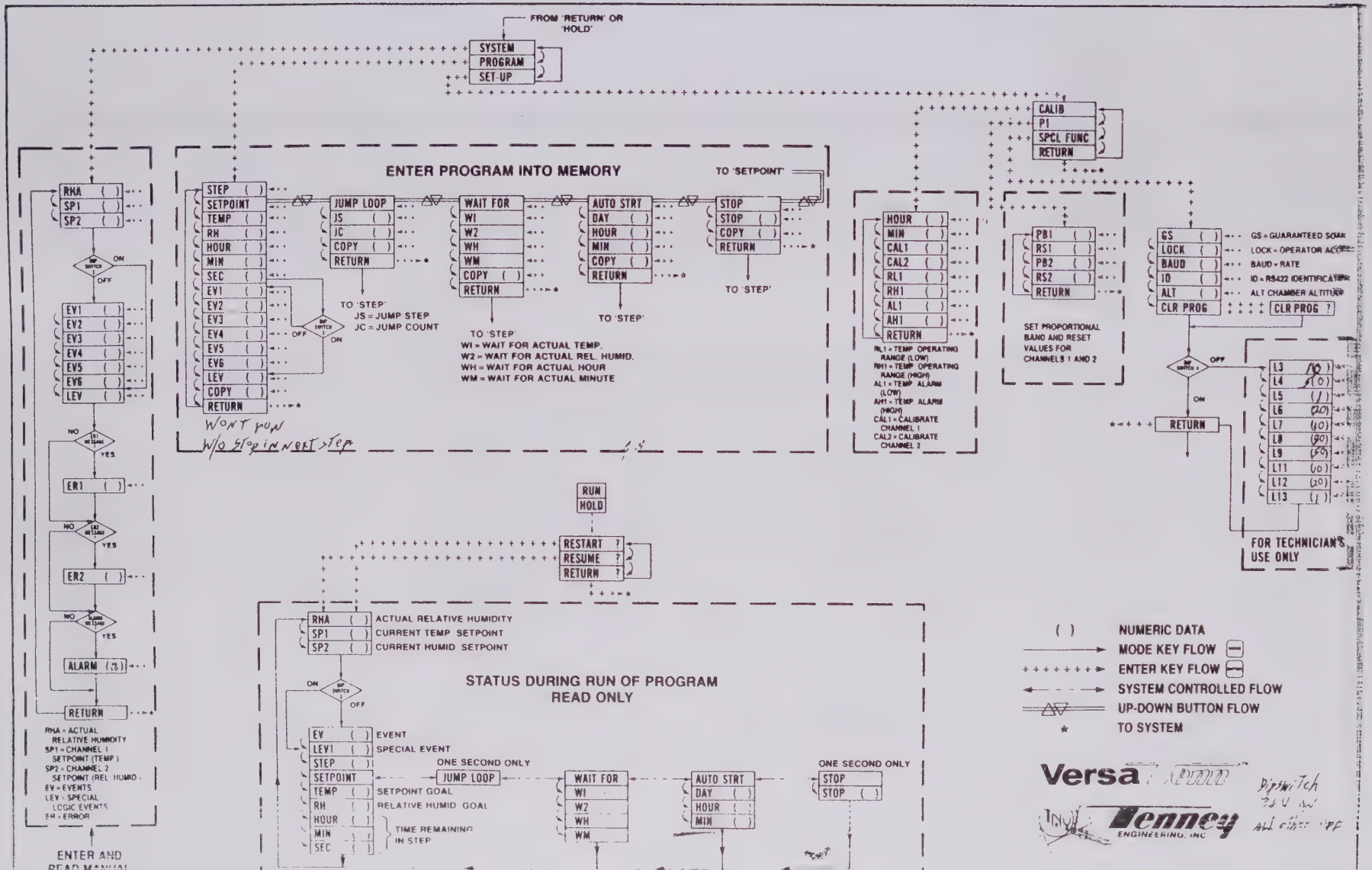
FROM 'RETURN' OR 'HOLD'
SYSTEM
PROGRAM
SET-UP
CALIB
P1
SPCL FUNC
RETURN
ENTER PROGRAM INTO MEMORY
TO 'SETPOINT'
STEP ( )
SETPOINT
TEMP ( )
RH ( )
HOUR ( )
MIN ( )
SEC ( )
EV1 ( )
EV2 ( )
EV3 ( )
EV4 ( )
EV5 ( )
EV6 ( )
LEV ( )
COPY ( )
RETURN
JUMP LOOP
JS ( )
JC ( )
COPY ( )
RETURN
TO 'STEP'
JS = JUMP STEP
JC = JUMP COUNT
WAIT FOR
W1
W2
WH
WM
COPY ( )
RETURN
TO 'STEP'
W1 = WAIT FOR ACTUAL TEMP.
W2 = WAIT FOR ACTUAL REL. HUMID.
WH = WAIT FOR ACTUAL HOUR
WM = WAIT FOR ACTUAL MINUTE
AUTO STRT
DAY ( )
HOUR ( )
MIN ( )
COPY ( )
RETURN
TO 'STEP'
STOP
STOP ( )
COPY ( )
RETURN
TO 'STEP'
WONT RUN W/O STOP IN NEXT STEP
RHA ( )
SP1 ( )
SP2 ( )
EV1 ( )
EV2 ( )
EV3 ( )
EV4 ( )
EV5 ( )
EV6 ( )
LEV ( )
ER1 ( )
ER2 ( )
ALARM ( )
RETURN
RHA = ACTUAL RELATIVE HUMIDITY
SP1 = CHANNEL 1 SETPOINT (TEMP.)
SP2 = CHANNEL 2 SETPOINT (REL. HUMID.)
EV = EVENTS
LEV = SPECIAL LOGIC EVENTS
ER = ERROR
ENTER AND READ MANUAL
HOUR ( )
MIN ( )
CAL1 ( )
CAL2 ( )
RL1 ( )
RH1 ( )
AL1 ( )
AH1 ( )
RETURN
RL1 = TEMP. OPERATING RANGE (LOW)
RH1 = TEMP. OPERATING RANGE (HIGH)
AL1 = TEMP. ALARM (LOW)
AH1 = TEMP. ALARM (HIGH)
CAL1 = CALIBRATE CHANNEL 1
CAL2 = CALIBRATE CHANNEL 2
PB1 ( )
RS1 ( )
PB2 ( )
RS2 ( )
RETURN
SET PROPORTIONAL BAND AND RESET VALUES FOR CHANNELS 1 AND 2
GS ( )
LOCK ( )
BAUD ( )
ID ( )
ALT ( )
CLR PROG
CLR PROG ?
GS = GUARANTEED SOAK
LOCK = OPERATOR ACC
BAUD = RATE
ID = RS422 IDENTIFICA
ALT CHAMBER ALTITUDE
RETURN
L3 ( )
L4 ( )
L5 ( )
L6 ( )
L7 ( )
L8 ( )
L9 ( )
L11 ( )
L12 ( )
L13 ( )
FOR TECHNICIAN'S USE ONLY
RUN
HOLD
RESTART ?
RESUME ?
RETURN ?
STATUS DURING RUN OF PROGRAM
READ ONLY
RHA ( ) ACTUAL RELATIVE HUMIDITY
SP1 ( ) CURRENT TEMP SETPOINT
SP2 ( ) CURRENT HUMID SETPOINT
EV ( ) EVENT
LEV1 ( ) SPECIAL EVENT
STEP ( )
SETPOINT
TEMP ( ) SETPOINT GOAL
RH ( ) RELATIVE HUMID GOAL
HOUR ( )
MIN ( )
SEC ( )
TIME REMAINING IN STEP
ONE SECOND ONLY
JUMP LOOP
WAIT FOR
W1
W2
WH
WM
AUTO STRT
DAY ( )
HOUR ( )
MIN ( )
ONE SECOND ONLY
STOP
STOP ( )
( ) NUMERIC DATA
MODE KEY FLOW
ENTER KEY FLOW
SYSTEM CONTROLLED FLOW
UP-DOWN BUTTON FLOW
TO SYSTEM
Versa
Tenney
ENGINEERING, INC
Dipswitch
ALL Either OFF

Tenney
ENGINEERING, INC.

SERVICING CASCADE REFRIGERATION SYSTEMS

By
Service Department, Tenney Engineering, Inc.

This article is aimed at the serviceman already familiar with conventional refrigeration systems. Here the cascade system is described and illustrated, and suggestions are given for its service, trouble-shooting and adjustment.

• • •

TNY Tenney ENGINEERING, INC.
The Largest and Most Experienced Manufacturer of High Technology Environmental Test Equipment
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ENVIRONMENTAL TEST EQUIPMENT

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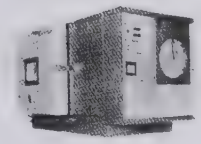
BENCHTOP TEMPERATURE CHAMBERS

Work space:
1¼ and 5 cubic feet.
Temperature range
-80°C to +200°C

Bulletins 108 and 123

BENCHTOP TEMPERATURE-HUMIDITY CHAMBERS

Workspace:
3 and 5 cubic feet
Temperature range:
-73°C to +200°C
Humidity capabilities
20% RH to 98% RH



Bulletins 101 and 123

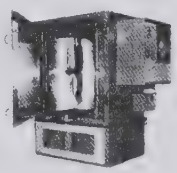
TENNEY SERIES HIGH-LOW TEMPERATURE AND TEMPERATURE HUMIDITY TEST CHAMBERS

Workspace
6 cubic feet
64 cubic feet
Temperature range:
-80°C to +200°C
Humidity: Optional

Bulletins 104 and 144

TH & T SERIES MODERATE RANGE TEMPERATURE-HUMIDITY CHAMBERS

Workspace:
27 cubic feet and
65 cubic feet
Temperature range:
Low to -18°C
High to +93°C
Humidity: Optional



Bulletin 139

MIL-STD 781 AGREE TEMPERATURE- VIBRATION CHAMBERS

Size:
Available in
sizes for mating with vibrator units having table tops from
4 square feet to
40 square feet
MicroTenn Standard

Bulletin 105

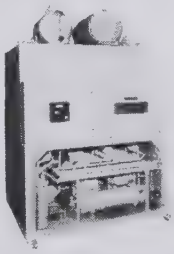
TENNEYSTRAT ALTITUDE- TEMPERATURE CHAMBERS

Workspace:
3.2 cubic feet thru
64 cubic feet
Temperature range
-73°C to +200°C
Altitude: to 200,000 feet
Humidity: Optional

Bulletin 141

LOW TEMPERATURE PROCESS EQUIPMENT

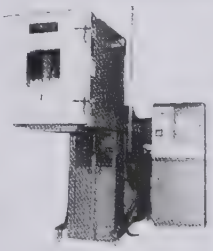
Packaged
Refrigeration Systems
Temperature range:
Low to -73°C
High to +121°C



Bulletin 114

VIBRATION/ TEMPERATURE CHAMBERS

Workspace:
Standard from
5 cubic feet to
64 cubic feet
Temperature range:
-73°C to +200°C
Humidity: Optional



Bulletin 102

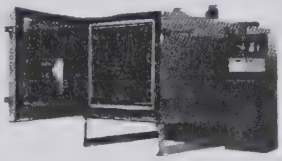
MULTI-RANGE PRECISION TEMPERATURE BATHS

Workspace:
One gallon and
nine gallon
Temperature range:
-73°C to +120°C

Bulletins 107 and 125

CERT SYSTEMS

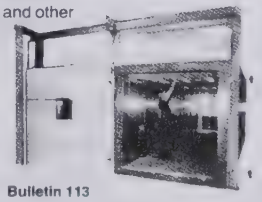
Combined Environment Reliability Testing Systems provide temperature, humidity, altitude, random vibration and cooling air simulation. Permits simulation of mission profile environments



Bulletin 134

WALK-IN ROOMS

For burn-in, temperature, humidity, altitude and other controlled environment testing. Custom-engineered in unitized or semi-unitized packages as well as modular panels.



Bulletin 113

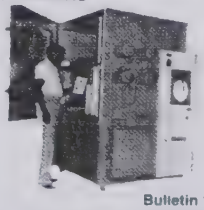
THERMAL VACUUM SPACE SIMULATORS

Workspace
Standard 1½ feet to
6 feet diameters
Vacuum capability:
to 2×10^{-8} Torr
Temperature
range: From
-196°C to +177°C

Bulletin 120

MECHANICALLY REFRIGERATED THERMAL SHOCK CHAMBERS

Workspace:
3, 5 and 8 cubic feet
Temperature range:
Top compartment
+200°C
Lower compartment
to -73°C
Center compartment
ambient optional
DigiTennStandard



Bulletin 121

VACUUM CHAMBERS AND VACUUM OVENS

Workspace
4 cubic feet thru
27 cubic feet
Temperature range:
to +150°C
Vacuum capability:
to 148 microns
(200,000 feet)

Bulletin 110

AUTOCLAVE SYSTEMS

Sizes
Small laboratory
models to large
production units
Temperature range
+400°C
Pressure to 800 psig
Vacuum: Optional

Bulletin 122

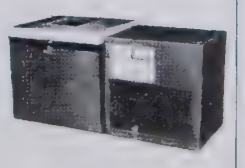
MICROTENN*

Microprocessor Programmer-Controller automatically signals chamber to perform programs entered via the keyboard or by the Microcassette transport. Computer interfaces are available

Bulletin 137

TENNEY SUB-ARCTIC INDUSTRIAL CABINETS AND COLD STORAGE CHESTS

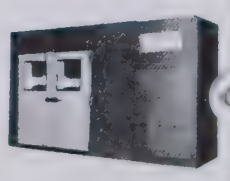
Workspace:
6 cubic feet thru
12 cubic feet
Temperature range:
Low to -84°C
High to +177°C



Bulletin 115

BURN-IN CHAMBERS

Size and number of doors may be specified to meet any burn-in requirement
Typical
temperature range
0°C to +60°C



Bulletin 133

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Introduction

This information is written to help the refrigeration serviceman repair and trouble-shoot low temperature cascade systems. It is assumed that the reader is familiar with standard refrigeration practice and is interested in the special techniques applicable to cascade systems.

History

Prior to the development of low boiling point refrigerants such as R 13 (-114°F) and R 503 (-127°F), reaching ultra low temperatures via mechanical refrigeration was difficult. R 22 was used down to -80°F, but its system had serious drawbacks. Large and cumbersome, the machinery was subject to the many troubles which afflict a compound system operating at suctions as low as 23" of vacuum.

The modern cascade system can reach as low as -120°F with suction pressures of 0 psig or higher. Compact, serviceable, and reliable, today's cascade system is found on thousands of environmental test chambers.

How It Works

Two types of cascade systems are popular: expansion valve and capillary tube. Both are discussed in the text, and capillary systems are shown in the schematics which comprise part of this paper.

Refrigerants with low boiling points have correspondingly high condensing pressures at normal ambients. They cannot be liquefied by conventional air or water cooled condensing units. Therefore, low temperature refrigerants are condensed by a separate refrigeration system called "the high stage". The sole job of the high stage in most cascade systems is to condense low stage refrigerant.

High Stage

The high stage is a conventional single stage system having a compressor, air or water cooled condenser, expansion valve, and evaporator. The evaporator is the cascade condenser, serving the low stage. Modern systems use R 502 in the high stage, making -50°F refrigerant temperature possible at 0 psig suction pressure.

Low Stage

The low stage is charged with refrigerant in vapor phase only, to a specified gauge pressure. When the low stage is idle, with all components

stabilized at 70°F, it will contain no liquid refrigerant. When the system is activated, the low stage compressor will pump hot gas through the discharge line to the desuperheater. The desuperheater, air or water cooled, removes some heat from the refrigerant gas, lightening the heat load on the cascade condenser. Leaving the desuperheater, the gas passes through an oil separator, then flows to the cascade condenser where it is liquefied by heat exchange with high stage refrigerant. After passing through a drier, cold low stage liquid refrigerant flows to the expansion valve.

Expansion Valve

The expansion valve meters refrigerant to the cooling coil located in the workspace. In the coil, refrigerant evaporates, absorbs heat, then returns to the compressor as a cold gas.

Frosted Lines Are Typical

A low stage characteristic is frosted liquid and suction lines. In a normal cascade system, the liquid line is always below +32°F. The suction line, returning from a -100°F evaporator, assuming 15° superheat, will also be far below freezing.

Expansion Tank

An expansion tank is provided to add volume to the low stage. Added volume permits the charging of additional refrigerant without increasing the standby or charging pressure beyond workable limits. Refrigerant gas is sucked out of the expansion tank during system operation: It is metered through a constant pressure valve, capillary tube, or needle valve, the valve or restriction regulating rate of gas entry into the system.

Load Limit Valve

Connected between expansion tank and discharge side of the low stage, a load limit valve acts as a relief device. It bleeds down or dumps gas into the expansion tank when low stage discharge pressure reaches valve setting, usually 185 to 240 psig. High pressures are generated when the low stage starts up but the load limit valve, acting as a relief, prevents the compressor from cycling on and off in response to signals from the high pressure cutout.

Leak Testing

Loss of refrigerant is the most common cause of refrigeration failure. Because of temperature extremes felt by its metal parts, the cascade system is particularly susceptible to leaks.

Check the entire system with an electronic leak detector. If the system is empty or at low pressure, boost pressure to 200 psig with inert gas (not oxygen!) diluted with a percentage of R 12. Test again.

A leak check while the system is at low temperature, -80°F or colder, is a must. Tighten and leak check expansion valve flanges, superheat adjustment caps and other mechanical joints while at low temperature.

You may use a halide torch to locate large leaks, but make your final test with the more sensitive electronic leak detector. This is especially important on the low stage. The low stage is gas charged with a relatively small quantity of refrigerant. Because of this, small leaks can quickly incapacitate the system.

Testing By Static Charge

One advantage of a gas charged system is that its tightness can be checked by periodic observation of static or standby pressure. You must read the pressure with all parts of the system at ambient temperature. This is important. The unit must be shut down at least 24-hours before a static pressure reading is taken. To eliminate the possibility of cooling the cascade condenser via the high stage pump-down cycle, all power to the unit must be off during the shut down period.

When reading static pressure, consider ambient temperature. Most static charge data are for a 70°F ambient, but pressure will decrease 5 psig for each 10°F decrease in temperature. Due to a large system's considerable thermal mass, several days may be required for all components to completely stabilize at a particular ambient.

Evacuation

Granted, refrigerants 13 and 503 are expensive, but there are times when charges must be bled off. A contaminated system must be cleaned and evacuated regardless of refrigerant expense.

If there is a possibility that moisture, non-condensibles or the wrong refrigerant contaminate a system, blow the charge and evacuate.

Select a two-stage pump capable of pumping the system down below 200 microns, and connect an appropriate gauge to read system pressure. The ordinary compound refrigeration gauge is inadequate, but a thermocouple gauge is ideal. Evacuating a leaky system is an exercise in futility; therefore, make sure the system is absolutely tight before beginning evacuation.

Charging a Low Stage

1. Do not charge liquid into the low stage.

2. Do not charge the system when it is below room temperature.

3. Do not use charging hoses on R 13 or R 503. Cylinder pressure exceeds 500 psig.

4. Never charge the unit when it is running.

As you will note from the above, low stage charging procedure differs from the conventional method. Correct charging pressure will be noted on the equipment nameplate or in the instructions. Remember, it is important that you charge by pressure, not by volume of refrigerant.

Use 1/4" copper tube between refrigerant cylinder and system. Open the cylinder valve very slowly. Charge into the suction side while closely watching the discharge gauge. When correct pressure is reached, shut off the refrigerant cylinder valve, allowing the system to equalize for 10 to 15 minutes. If the pressure drops, again crack open the cylinder valve, slowly raising the pressure. Always take enough time: Systems with expansion tanks connected by a capillary tube or restrictor valve may need several minutes for gas pressure to equalize.

Keep the refrigerant cylinder upright when charging. Above all, be careful! Don't over-pressurize. Disconnect the cylinder immediately that charging is complete. A leaky cylinder valve could continue to bleed high pressure refrigerant into the system, possibly causing it to rupture. Don't take chances; the saturation pressures of low temperature refrigerants are extremely high.

Drawing No. 1

A small cascade system, using two 1/3 hp hermetic compressors is delineated in this schematic. The high stage is charged with 14 oz. of R 12 the low stage carrying a static pressure of 52 psig at room temperature. 10 c. c. of pentane is added to the low stage charge to help prevent waxing of the lubricant at extremely low temperatures.

Flow of refrigerant in the high stage is from compressor C2 to the air-cooled condenser. As a liquid, R 12 flows from condenser to capillary tube drier assembly D2 which meters refrigerant to the cascade condenser. After evaporating in the condenser assembly, which is a heat-exchanger, R 12 returns to the compressor C2 via the suction line and accumulator ACC.

Function of pressure switch PS2 is to energize the low stage compressor after the high stage has started. Purpose of the arrangement is to prevent both compressors from hitting the power line at the same instant.

Refrigerant flow in the low stage is from the compressor through the desuperheater to the cascade condenser where gaseous R 503 is cooled and liquefied. Capillary tube assembly D1 meters R 503 into the evaporator 11771-2 which cools the chamber. From the evaporator, refrigerant returns to the compressor via the suction line.

Excess refrigerant is stored in the expansion tank and is fed back to the system on demand through capillary tube 5.

Solenoid valve SV serves two purposes: On a cooling "off" cycle it functions as an artificial loading valve, partially by-passing the evaporator and reducing cooling capacity. Refrigeration is modulated through this valve, not by cycling of the compressors. Valve SV also functions as a dump valve. Responding to signals from pressure switch PS1, it opens when head pressure exceeds a predetermined pressure setpoint, typically 280 psig.

Drawing No. 2

The refrigeration system shown is similar to that described on drawing no. 1. Hot gas from high stage compressor C2 is used to heat the chamber door mullion before entering air cooled condenser CON/20. Switch PS2 energizes the low stage compressor, and switch PS1 operates the dump valve SV14, that valve also being under command of the temperature controller which uses it to modulate refrigeration capacity.

Drawing No. 3

When operated in cascade mode, the system shown on this schematic functions essentially the same as the two systems previously described. R 502 flow is from compressor C2, through mullion heater to condenser, then through cap tube assembly D/9 to the cascade condenser. Return flow is via the suction line and accumulator ACC/21. Flow of R 503 is from compressor through cascade condenser and cap tube D/8 to the low temperature coil, then back to the compressor through the suction line. Valve SV14 functions as modulating (artificial loading) and dump valve in the usual manner.

Low stage R 503 compressor C1 is shut down when the system operates in single stage mode for "ambient" cooling and workspace dehumidification. R 502 flow is then as follows:

After being liquefied in the condenser CON/20, refrigerant flows to solenoid valves SV1 and SV4. When the dry bulb temperature controller calls for cooling, it opens valve SV1, admitting refrigerant to the ambient cooling coil. After evaporating, the R 12, as a cool gas, returns to the compressor via evaporator pressure regulator AEV/6 and the suction line. Purpose of the regulator AEV/6 is to prevent the ambient coil from operating too cold, a condition which is undesirable when the chamber is being operated at high humidity.

When the wet bulb controller or humidity control signals for decreased workspace humidity, control voltage is applied to solenoid valve SV4. Refrigerant is admitted to the dehumidification coil, returning to the high stage compressor via the suction line.

Capillary tube D/9 which feeds the cascade condenser is not valved off while the high stage operates in "ambient" single stage configuration. It functions as a by-pass so that when solenoid valves SV1 and SV4 are both closed there remains a path through which refrigerant can circulate. On most larger systems, this line is valved off, and other forms of by-pass are provided.

CASCADE REFRIGERATION GLOSSARY

Cascade Condenser is the high stage system's evaporator and the low stage system's condenser. Can be either tube in tube with the low stage refrigerant in the outside tube or tube in shell with the low stage refrigerant in the shell.

Desuperheater can be either air or water cooled. Its purpose is to remove some heat from the low stage discharge gas and thereby lighten the load on the cascade condenser. On air cooled units, a few passes at the top of the high stage condenser are used as the desuperheater. Water cooled desuperheaters are either tube in tube or shell in tube. The water flow is usually in series with the high stage condenser.

Low Stage is the low temperature stage or system that cools the chamber or work space evaporator. Common low stage refrigerants are R 13, R 503, and R 14. Low stage refrigerants have low boiling points and correspondingly low condensing temperatures.

High Stage usually R 12, R 502, or R 22, is used to cool the low stage condenser. Some high stage systems are used, as a separate function, to provide moderate cooling for the chamber work space.

Load Limit Valve is sometimes called dump or blow down valve. Located between the discharge side of the low stage and the expansion tank, this valve opens, allowing gas to flow into the tank, thereby reducing head pressure.

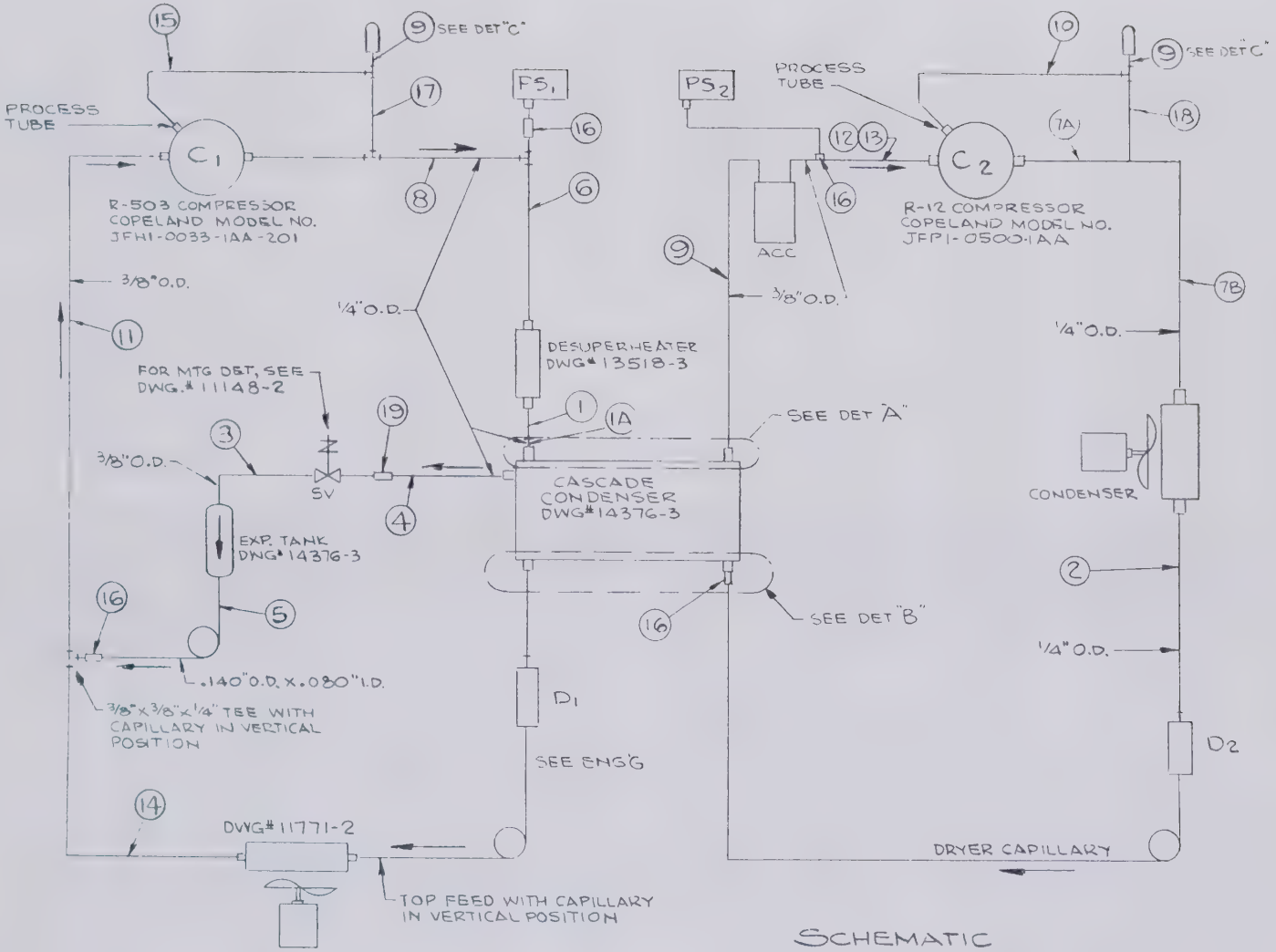
Expansion Tank is used in the low stage to provide additional system volume. It allows the use of sufficient refrigerant charge, while maintaining reasonable standby or static pressure.

Static Charge is the gauge pressure indicated in the low stage. The equipment manufacturer will designate proper static or standby pressure for a particular unit. A typical nameplate will specify low stage R 13, 7 lbs. static 120 psig. This means that if you add R 13 gas to an evacuated unit, until system pressure is 120 psig, you will have removed 7 lbs. from your cylinder.

Pull Down Time is the length of time required to lower air in the chamber work space from ambient, a nominal 70°F, to desired low temperature. The temperature is measured at the discharge of the fan. Air is normally drawn over the evaporator and discharged into the work space.

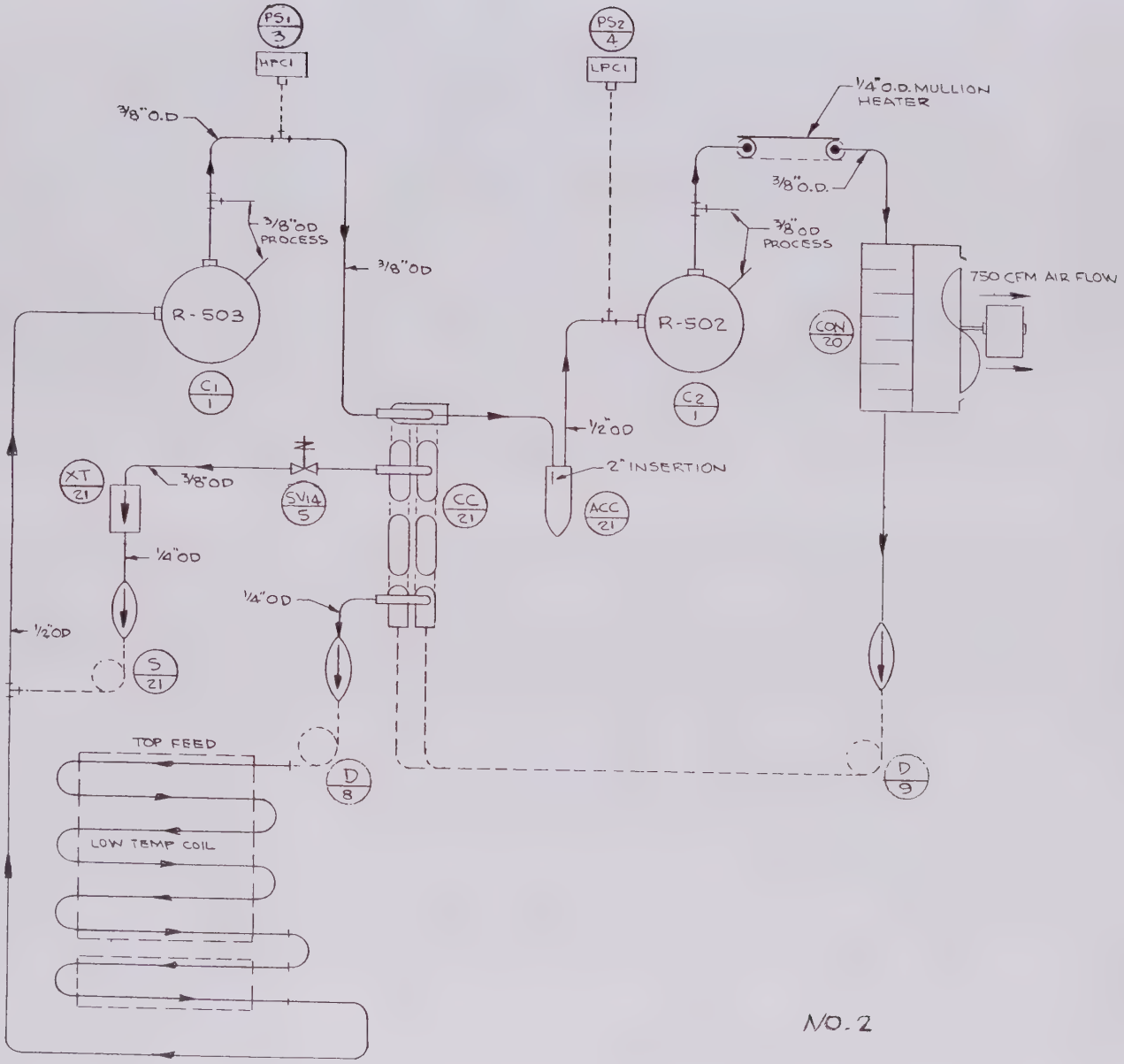
Sub Zero Cooling is the term used to describe the mode of cooling wherein the low stage refrigerant is used to cool the work space.

Ambient Cooling describes the high stage unit being used to cool the work space via its own evaporator.

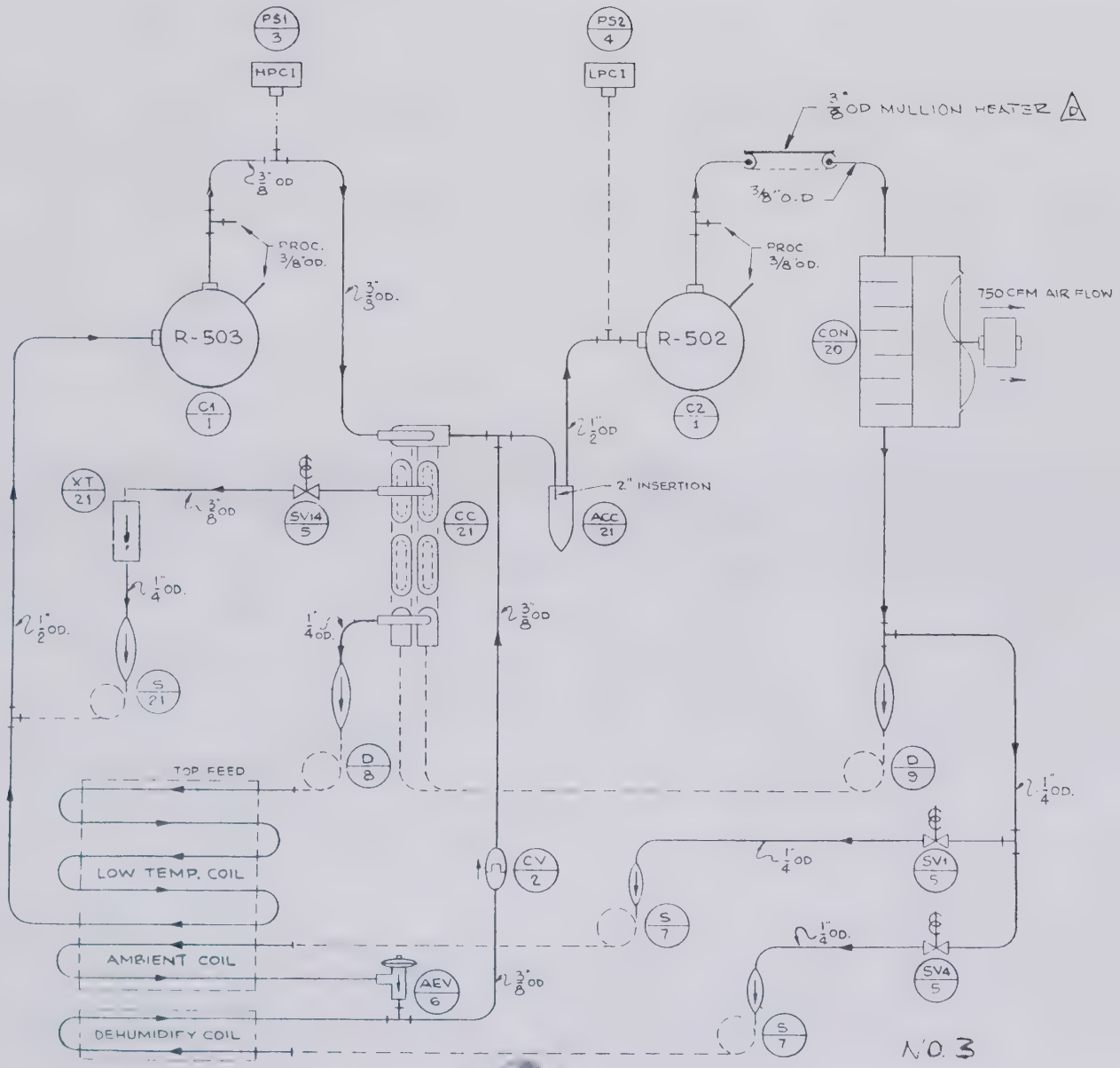


SCHEMATIC

NO. 1


PS1
3
HPCI
PS2
4
LPCI
3/8"O.D
3/8"OD PROCESS
3/8"OD
R-503
C1
1
1/4"O.D. MULLION HEATER
3/8"O.D.
3/8"OD PROCESS
R-502
C2
1
CON
20
750 CFM AIR FLOW
1/2"OD
2" INSERTION
ACC
21
XT
21
3/8"OD
SV14
5
CC
21
1/4"OD
1/4"OD
1/2"OD
S
21
TOP FEED
D
8
LOW TEMP COIL
D
9

NO. 2


PS1 3
HPC1
PS2 4
LPC1
3/8 OD MULLION HEATER D
3/8 OD
3/8" O.D
PROC. 3/8 OD.
PROC 3/8 OD.
3/8 OD.
R-503
R-502
CON 20
750 CFM AIR FLOW
C1 1
C2 1
1/2 OD
2" INSERTION
XT 21
3/8 OD
SV14 5
CC 21
ACC 21
1/4 OD.
1/2 OD.
1/4 OD.
3/8 OD
S 21
D 8
D 9
TOP FEED
1/4 OD.
LOW TEMP. COIL
CV 2
1/4 OD
SV1 5
S 7
AMBIENT COIL
AEV 6
3/8 OD
1/4 OD.
SV4 5
DEHUMIDIFY COIL
S 7
NO. 3

MINCO

RESISTANCE TEMPERATURE TABLE
U.S. INDUSTRIAL SPEC. $R_{100C}/R_{0C} = 1.3911$
PLATINUM RESISTANCE THERMOMETER
100 OHMS AT 0°C.

TABLE 11-100

7300 Commerce Lane ! Minneapolis, Minnesota 55432 ! TWX: 910-576-2848 ! Telephone : (612) 786-3121

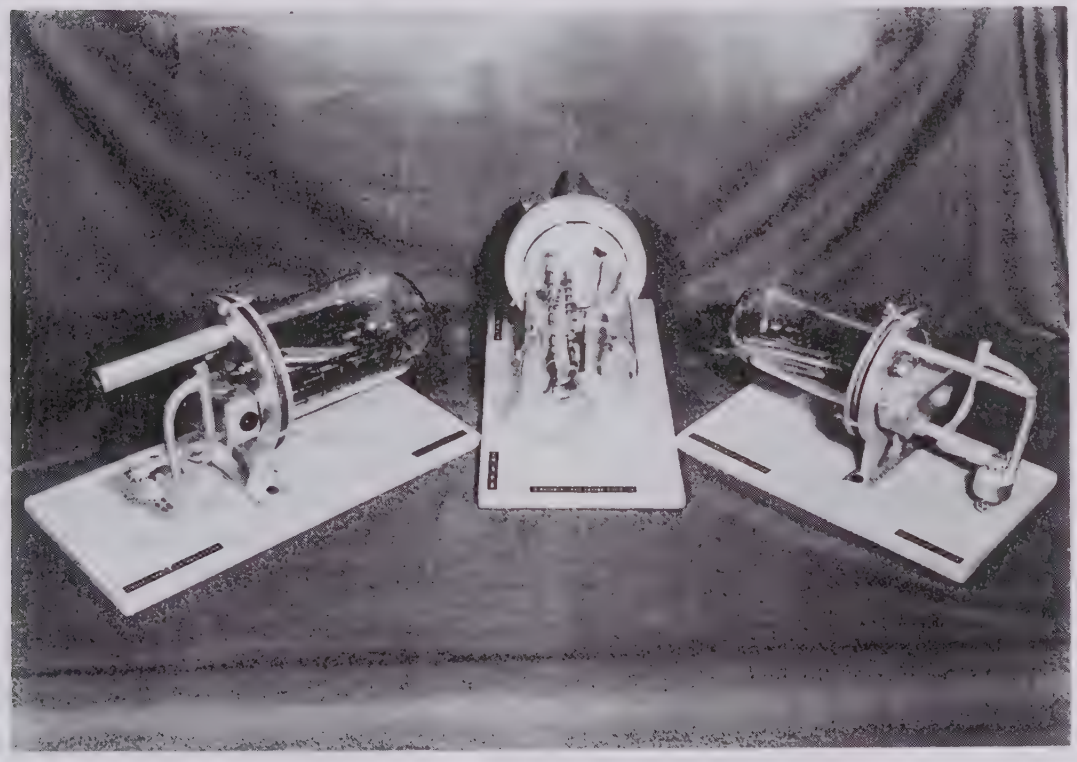
T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
-200.0	17.26	-155.0	36.67	-110.0	55.51	-65.0	73.93
-199.0	17.70	-154.0	37.09	-109.0	55.93	-64.0	74.34
-198.0	18.14	-153.0	37.52	-108.0	56.34	-63.0	74.74
-197.0	18.58	-152.0	37.94	-107.0	56.75	-62.0	75.15
-196.0	19.01	-151.0	38.37	-106.0	57.17	-61.0	75.55
-195.0	19.45	-150.0	38.79	-105.0	57.58	-60.0	75.96
-194.0	19.89	-149.0	39.21	-104.0	57.99	-59.0	76.36
-193.0	20.32	-148.0	39.63	-103.0	58.40	-58.0	76.77
-192.0	20.76	-147.0	40.06	-102.0	58.81	-57.0	77.17
-191.0	21.20	-146.0	40.48	-101.0	59.23	-56.0	77.58
-190.0	21.63	-145.0	40.90	-100.0	59.64	-55.0	77.98
-189.0	22.07	-144.0	41.32	-99.0	60.05	-54.0	78.39
-188.0	22.50	-143.0	41.74	-98.0	60.45	-53.0	78.79
-187.0	22.94	-142.0	42.16	-97.0	60.87	-52.0	79.19
-186.0	23.37	-141.0	42.59	-96.0	61.28	-51.0	79.60
-185.0	23.80	-140.0	43.01	-95.0	61.69	-50.0	80.00
-184.0	24.24	-139.0	43.43	-94.0	62.10	-49.0	80.40
-183.0	24.67	-138.0	43.85	-93.0	62.51	-48.0	80.81
-182.0	25.10	-137.0	44.27	-92.0	62.92	-47.0	81.21
-181.0	25.54	-136.0	44.69	-91.0	63.33	-46.0	81.61
-180.0	25.97	-135.0	45.10	-90.0	63.74	-45.0	82.01
-179.0	26.40	-134.0	45.52	-89.0	64.15	-44.0	82.42
-178.0	26.83	-133.0	45.94	-88.0	64.56	-43.0	82.82
-177.0	27.26	-132.0	46.36	-87.0	64.97	-42.0	83.22
-176.0	27.69	-131.0	46.78	-86.0	65.38	-41.0	83.62
-175.0	28.12	-130.0	47.20	-85.0	65.79	-40.0	84.03
-174.0	28.55	-129.0	47.62	-84.0	66.20	-39.0	84.43
-173.0	28.98	-128.0	48.03	-83.0	66.61	-38.0	84.83
-172.0	29.41	-127.0	48.45	-82.0	67.02	-37.0	85.23
-171.0	29.84	-126.0	48.87	-81.0	67.42	-36.0	85.63
-170.0	30.27	-125.0	49.28	-80.0	67.83	-35.0	86.03
-169.0	30.70	-124.0	49.70	-79.0	68.24	-34.0	86.43
-168.0	31.13	-123.0	50.12	-78.0	68.65	-33.0	86.84
-167.0	31.56	-122.0	50.53	-77.0	69.06	-32.0	87.24
-166.0	31.98	-121.0	50.95	-76.0	69.46	-31.0	87.64
-165.0	32.41	-120.0	51.37	-75.0	69.87	-30.0	88.04
-164.0	32.84	-119.0	51.78	-74.0	70.28	-29.0	88.44
-163.0	33.27	-118.0	52.20	-73.0	70.68	-28.0	88.84
-162.0	33.69	-117.0	52.61	-72.0	71.09	-27.0	89.24
-161.0	34.12	-116.0	53.03	-71.0	71.50	-26.0	89.64
-160.0	34.54	-115.0	53.44	-70.0	71.90	-25.0	90.04
-159.0	34.97	-114.0	53.86	-69.0	72.31	-24.0	90.44
-158.0	35.40	-113.0	54.27	-68.0	72.72	-23.0	90.84
-157.0	35.82	-112.0	54.68	-67.0	73.12	-22.0	91.24
-156.0	36.25	-111.0	55.10	-66.0	73.53	-21.0	91.64

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
-20.0	92.04	25.0	109.89	70.0	127.50	115.0	144.87
-19.0	92.44	26.0	110.28	71.0	127.89	116.0	145.26
-18.0	92.84	27.0	110.67	72.0	128.28	117.0	145.64
-17.0	93.24	28.0	111.07	73.0	128.66	118.0	146.02
-16.0	93.63	29.0	111.46	74.0	129.05	119.0	146.41
-15.0	94.03	30.0	111.86	75.0	129.44	120.0	146.79
-14.0	94.43	31.0	112.25	76.0	129.83	121.0	147.17
-13.0	94.83	32.0	112.64	77.0	130.22	122.0	147.55
-12.0	95.23	33.0	113.03	78.0	130.60	123.0	147.94
-11.0	95.63	34.0	113.43	79.0	130.99	124.0	148.32
-10.0	96.02	35.0	113.82	80.0	131.38	125.0	148.70
-9.0	96.42	36.0	114.21	81.0	131.77	126.0	149.08
-8.0	96.82	37.0	114.61	82.0	132.15	127.0	149.47
-7.0	97.22	38.0	115.00	83.0	132.54	128.0	149.85
-6.0	97.62	39.0	115.39	84.0	132.93	129.0	150.23
-5.0	98.01	40.0	115.78	85.0	133.32	130.0	150.61
-4.0	98.41	41.0	116.18	86.0	133.70	131.0	150.99
-3.0	98.81	42.0	116.57	87.0	134.09	132.0	151.37
-2.0	99.21	43.0	116.96	88.0	134.48	133.0	151.76
-1.0	99.60	44.0	117.35	89.0	134.86	134.0	152.14
0.0	100.00	45.0	117.74	90.0	135.25	135.0	152.52
1.0	100.40	46.0	118.13	91.0	135.64	136.0	152.90
2.0	100.79	47.0	118.53	92.0	136.02	137.0	153.28
3.0	101.19	48.0	118.92	93.0	136.41	138.0	153.66
4.0	101.59	49.0	119.31	94.0	136.79	139.0	154.04
5.0	101.98	50.0	119.70	95.0	137.18	140.0	154.42
6.0	102.38	51.0	120.09	96.0	137.57	141.0	154.80
7.0	102.74	52.0	120.48	97.0	137.95	142.0	155.18
8.0	103.17	53.0	120.87	98.0	138.34	143.0	155.56
9.0	103.57	54.0	121.26	99.0	138.72	144.0	155.94
10.0	103.96	55.0	121.65	100.0	139.11	145.0	156.32
11.0	104.36	56.0	122.04	101.0	139.49	146.0	156.70
12.0	104.75	57.0	122.43	102.0	139.88	147.0	157.08
13.0	105.15	58.0	122.82	103.0	140.26	148.0	157.46
14.0	105.55	59.0	123.21	104.0	140.65	149.0	157.84
15.0	105.94	60.0	123.60	105.0	141.03	150.0	158.22
16.0	106.34	61.0	123.99	106.0	141.42	151.0	158.60
17.0	106.73	62.0	124.38	107.0	141.80	152.0	158.98
18.0	107.13	63.0	124.77	108.0	142.19	153.0	159.36
19.0	107.52	64.0	125.16	109.0	142.57	154.0	159.74
20.0	107.92	65.0	125.55	110.0	142.95	155.0	160.12
21.0	108.31	66.0	125.94	111.0	143.34	156.0	160.50
22.0	108.70	67.0	126.33	112.0	143.72	157.0	160.87
23.0	109.10	68.0	126.72	113.0	144.11	158.0	161.25
24.0	109.49	69.0	127.11	114.0	144.49	159.0	161.63

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
160.0	162.01	205.0	178.91	250.0	195.57	295.0	212.00
161.0	162.39	206.0	179.28	251.0	195.94	296.0	212.36
162.0	162.77	207.0	179.66	252.0	196.31	297.0	212.73
163.0	163.14	208.0	180.03	253.0	196.68	298.0	213.09
164.0	163.52	209.0	180.40	254.0	197.04	299.0	213.45
165.0	163.90	210.0	180.77	255.0	197.41	300.0	213.81
166.0	164.28	211.0	181.15	256.0	197.78	301.0	214.17
167.0	164.65	212.0	181.52	257.0	198.15	302.0	214.54
168.0	165.03	213.0	181.89	258.0	198.51	303.0	214.90
169.0	165.41	214.0	182.26	259.0	198.88	304.0	215.26
170.0	165.79	215.0	182.63	260.0	199.25	305.0	215.62
171.0	166.16	216.0	183.01	261.0	199.61	306.0	215.98
172.0	166.54	217.0	183.38	262.0	199.98	307.0	216.34
173.0	166.92	218.0	183.75	263.0	200.34	308.0	216.70
174.0	167.29	219.0	184.12	264.0	200.71	309.0	217.06
175.0	167.67	220.0	184.49	265.0	201.08	310.0	217.42
176.0	168.05	221.0	184.86	266.0	201.44	311.0	217.79
177.0	168.42	222.0	185.23	267.0	201.81	312.0	218.15
178.0	168.80	223.0	185.60	268.0	202.17	313.0	218.51
179.0	169.17	224.0	185.98	269.0	202.54	314.0	218.87
180.0	169.55	225.0	186.35	270.0	202.90	315.0	219.23
181.0	169.93	226.0	186.72	271.0	203.27	316.0	219.59
182.0	170.30	227.0	187.09	272.0	203.64	317.0	219.95
183.0	170.68	228.0	187.46	273.0	204.00	318.0	220.31
184.0	171.05	229.0	187.83	274.0	204.37	319.0	220.67
185.0	171.43	230.0	188.20	275.0	204.73	320.0	221.03
186.0	171.80	231.0	188.57	276.0	205.09	321.0	221.38
187.0	172.18	232.0	188.94	277.0	205.46	322.0	221.74
188.0	172.55	233.0	189.31	278.0	205.82	323.0	222.10
189.0	172.93	234.0	189.68	279.0	206.19	324.0	222.46
190.0	173.30	235.0	190.05	280.0	206.55	325.0	222.82
191.0	173.68	236.0	190.42	281.0	206.92	326.0	223.18
192.0	174.05	237.0	190.78	282.0	207.28	327.0	223.54
193.0	174.43	238.0	191.15	283.0	207.64	328.0	223.90
194.0	174.80	239.0	191.52	284.0	208.01	329.0	224.26
195.0	175.18	240.0	191.89	285.0	208.37	330.0	224.61
196.0	175.55	241.0	192.26	286.0	208.74	331.0	224.97
197.0	175.92	242.0	192.63	287.0	209.10	332.0	225.33
198.0	176.30	243.0	193.00	288.0	209.46	333.0	225.69
199.0	176.67	244.0	193.37	289.0	209.82	334.0	226.05
200.0	177.04	245.0	193.73	290.0	210.19	335.0	226.40
201.0	177.42	246.0	194.10	291.0	210.55	336.0	226.76
202.0	177.79	247.0	194.47	292.0	210.91	337.0	227.12
203.0	178.16	248.0	194.84	293.0	211.28	338.0	227.48
204.0	178.54	249.0	195.21	294.0	211.64	339.0	227.83

T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)	T(C)	R(OHMS)
340.0	228.19	385.0	244.14	430.0	259.86	475.0	275.34
341.0	228.55	386.0	244.50	431.0	260.21	476.0	275.68
342.0	228.91	387.0	244.85	432.0	260.55	477.0	276.02
343.0	229.26	388.0	245.20	433.0	260.90	478.0	276.36
344.0	229.62	389.0	245.55	434.0	261.25	479.0	276.70
345.0	229.98	390.0	245.90	435.0	261.59	480.0	277.05
346.0	230.33	391.0	246.25	436.0	261.94	481.0	277.39
347.0	230.69	392.0	246.60	437.0	262.28	482.0	277.73
348.0	231.04	393.0	246.96	438.0	262.63	483.0	278.07
349.0	231.40	394.0	247.31	439.0	262.98	484.0	278.41
350.0	231.76	395.0	247.66	440.0	263.32	485.0	278.75
351.0	232.11	396.0	248.01	441.0	263.67	486.0	279.09
352.0	232.47	397.0	248.36	442.0	264.01	487.0	279.43
353.0	232.82	398.0	248.71	443.0	264.36	488.0	279.77
354.0	233.18	399.0	249.06	444.0	264.70	489.0	280.11
355.0	233.54	400.0	249.41	445.0	265.05	490.0	280.45
356.0	233.89	401.0	249.76	446.0	265.39	491.0	280.79
357.0	234.25	402.0	250.11	447.0	265.74	492.0	281.13
358.0	234.60	403.0	250.46	448.0	266.08	493.0	281.47
359.0	234.96	404.0	250.81	449.0	266.43	494.0	281.80
360.0	235.31	405.0	251.16	450.0	266.77	495.0	282.14
361.0	235.67	406.0	251.51	451.0	267.11	496.0	282.48
362.0	236.02	407.0	251.86	452.0	267.46	497.0	282.82
363.0	236.37	408.0	252.21	453.0	267.80	498.0	283.16
364.0	236.73	409.0	252.56	454.0	268.15	499.0	283.50
365.0	237.08	410.0	252.90	455.0	268.49	500.0	283.84
366.0	237.44	411.0	253.25	456.0	268.83	501.0	284.18
367.0	237.79	412.0	253.60	457.0	269.18	502.0	284.51
368.0	238.15	413.0	253.95	458.0	269.52	503.0	284.85
369.0	238.50	414.0	254.30	459.0	269.86	504.0	285.19
370.0	238.85	415.0	254.65	460.0	270.21	505.0	285.53
371.0	239.21	416.0	255.00	461.0	270.55	506.0	285.87
372.0	239.56	417.0	255.34	462.0	270.89	507.0	286.20
373.0	239.91	418.0	255.69	463.0	271.24	508.0	286.54
374.0	240.27	419.0	256.04	464.0	271.58	509.0	286.88
375.0	240.62	420.0	256.39	465.0	271.92	510.0	287.22
376.0	240.97	421.0	256.74	466.0	272.26	511.0	287.55
377.0	241.33	422.0	257.08	467.0	272.61	512.0	287.89
378.0	241.68	423.0	257.43	468.0	272.95	513.0	288.23
379.0	242.03	424.0	257.78	469.0	273.29	514.0	288.56
380.0	242.38	425.0	258.13	470.0	273.63	515.0	288.90
381.0	242.74	426.0	258.47	471.0	273.97	516.0	289.24
382.0	243.09	427.0	258.82	472.0	274.32	517.0	289.57
383.0	243.44	428.0	259.17	473.0	274.66	518.0	289.91
384.0	243.79	429.0	259.51	474.0	275.00	519.0	290.25

HOW TO USE AND SERVICE
TENNEY VAPOR–FLO HUMIDITY GENERATORS



GENERAL

Tenney Vapor-Flo humidifiers are compact, integral highly engineered vapor generators on which patent is applied for. Currently manufactured in five output capacities, the generators are designed specifically for the humidification of environmental test equipment.

DESCRIPTION

Water is automatically metered into a Pyrex glass, thick-wall bell jar having fiberglass insulation and an aluminum cover over the assembly. Inside the jar, water is heated and vaporized by an immersion heater: Generated vapor then passes through a copper

tube from the vapor space to the humidified test chamber. An important design objective is the generator's ability to increase chamber or room humidity with minimum effect on dry bulb temperature.

WATER LEVEL CONTROL

Within the bell jar, water level is accurately controlled by a float. Connected to a shut-off valve through an extension arm, the float controls water-level much as a carburetor's float maintains fuel-level in the carburetor float bowl.

OVERHEAT PROTECTION

Wrapped around the immersion heater is the sensing element of a quick-response protective thermostat having automatic reset. Should water supply fail and water-level fall below the immersion heater, the protective thermostat breaks the circuit and shuts down the heater. Thermostat setting is 335°F and is non-adjustable.

When the immersion heater cools, the thermostat re-establishes circuit connection and the generator is again activated.

WATER OVERFLOW PREVENTION

In the unlikely event that the water level float should stick open, allowing water to flow uncontrolled into the bell-jar, there will be no flooding of the work chamber or room through the humidity feed line. An overflow line is incorporated. Should water-level rise more than a fixed distance above the immersion heater, and approach the humidity line level, excess water will drain out of the overflow to the drain.

APPROX. GENERATING CAPACITY

Approximate vapor generating capacity of various models is given in the table below. This is a general guide. Please remember that these data are approximate. Variables are such factors as line voltage, incoming water temperature, back pressure and condition of immersion heater.

Heater	Max. Output
300 watt	.9 lbs./hr.
750 watt	2.2 lbs./hr.
1,000 watt	3.0 lbs./hr.
1,500 watt	4.5 lbs./hr.
2,000 watt	6.0 lbs./hr.

IMMERSION HEATER RESISTANCES

Approximate immersion heater ohmic resistances are given in the following table. Resistances are those at 75°F and may vary by 15% or more without falling out of tolerance. The table is given to help the user and service man identify heater size and to locate shorted

or open elements.

Heater		Nom. Resis.
115 volt,	300 watt	43 ohm
220 volt,	750 watt	63 ohm
220 volt,	1,000 watt	47 ohm
220 volt,	1,500 watt	31 ohm
220 volt,	2,000 watt	24 ohm

OPERATING THE HUMIDIFIER

Once the water supply has been turned on, operation is automatic. Simply be sure that inlet water is turned on.

ABOUT THE WATER SUPPLY

Inlet water should be soft and clean. Otherwise, crusting and contamination of the float, heater and bell jar will take place. If demineralized water is not locally obtainable, we suggest you install a Tenney Cartridge Deionizer Kit, Model 11-11-2A in the water feed line. The kit is convenient, easy to install, and has a capacity of 500 grains as $CaCO_3$. Extra cartridges are available from Tenney's stock.

OPERATIONAL CHECKS

About every twenty-five hours of operation, oftener if you desire, open the drain cock (drain and deconcentrator valve) and allow water to drain for a few minutes. This will flush out concentrated salts and impurities.

Every hundred hours of operation, pull back the bell jar insulation and inspect the float, heater and jar. When they appear crusted with salts and scale, clean the assembly.

CLEANING

Shut off the water supply. Drain the bell jar. Pour two or three ounces of Tenney's Humiclean down the vent. Turn on the water supply (with drain closed off). Allow the water level to normalize, then operate the humidifier for about half an hour. Shut off the water. Drain the Humiclean solution. Turn on the water and flush the bell jar for a few minutes.

REMOVING THE BELL JAR

First, remove the aluminum-covered insulating sleeve by sliding it over the end of the bell jar remote from the water and power connection.

Spin off the three wing nuts: top one last. Slip off the outer ring flange then remove the glass bell jar. The immersion heater, thermostat element, float and float valve are now exposed.

float valve are now exposed.

Careful please! Usually, the bell jar flange will adhere to the humidifier bracket. Loosen it gently. Prying with a screwdriver may chip or break the glass.

When reassembling, smear a thin coat of silicone grease on the bell jar's ground flange to prevent its sticking to the gasket. Tighten the three wing nuts finger tight only; don't use pliers.

TROUBLE SHOOTING

Generator will not deliver vapor: See that there is adequate water in bell jar. Measure voltage on immersion heater terminals. Test thermostat for continuity. Measure immersion heater resistance.

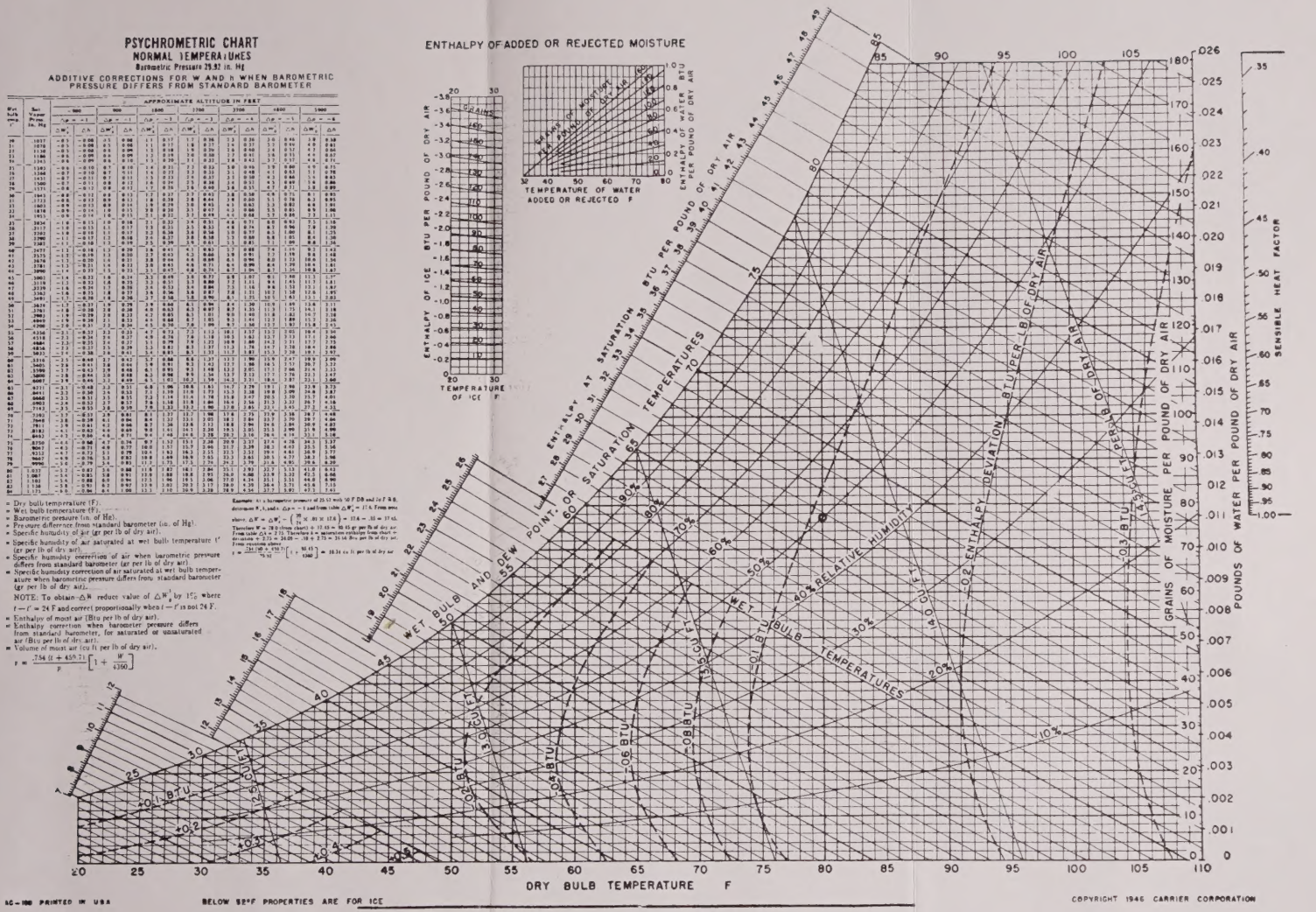
Immersion heater cycles on and off: This is usually an indication of low water level. Be sure water supply is adequate. Clean the water inlet valve and washer of contamination. Flush and clean the bell jar. Finally, adjust the float so that water level is at centerline or slightly above. You may have to bend the float arm slightly. Careful. Don't damage the float. If the element still cycles, replace the thermostat assembly. Wind the sensing element on the immersion heater approximately as the original was wound.

Water continually runs or dribbles from over-flow: The float valve is leaking. Shut off water. Remove the bell jar insulating sleeve and bell jar. Remove and disassemble the float valve. Shake the float. If it is water-logged, replace it. Clean the valve and reassemble. If the valve still leaks after cleaning - replace.

Humidifier operates but vapor volume is low: Examine the humidity feed line and remove any obstruction. Thoroughly clean the immersion heater. Be sure the water-level is approximately at the bell jar's centerline. Measure the immersion heater's resistance. Unusually high resistance would indicate lack of heating power. With the Vapor-Flo unit operating, measure voltage at the immersion heater terminals. Voltage should be no lower than 10% below nominal. (Chief cause of low immersion heater voltage is an inadequate power cord.)

SPARE PARTS ARE AVAILABLE

Complete spare parts are available from Tenney's Service Department. When you order, please specify the model and serial number of the Tenney environmental equipment served by your Vapor-Flo Humidity Generator.


PSYCHROMETRIC CHART
NORMAL TEMPERATURES
Barometric Pressure 29.92 in. Hg
ADDITIVE CORRECTIONS FOR W AND h WHEN BAROMETRIC PRESSURE DIFFERS FROM STANDARD BAROMETER
APPROXIMATE ALTITUDE IN FEET
ENTHALPY OF ADDED OR REJECTED MOISTURE
ENTHALPY OF ICE BTU PER POUND OF DRY AIR
TEMPERATURE OF ICE F
ENTHALPY OF WATER BTU PER POUND OF DRY AIR
TEMPERATURE OF WATER ADDED OR REJECTED F
ENTHALPY AT SATURATION BTU PER POUND OF DRY AIR
DEW POINT OR SATURATION TEMPERATURES
WET BULB AND DEW POINT TEMPERATURES
RELATIVE HUMIDITY
WET BULB TEMPERATURES
ENTHALPY DEVIATION BTU PER LB OF DRY AIR
VOLUME CU FT PER LB OF DRY AIR
GRAINS OF MOISTURE PER POUND OF DRY AIR
POUNDS OF WATER PER POUND OF DRY AIR
SENSIBLE HEAT FACTOR
DRY BULB TEMPERATURE F
BELOW 32°F PROPERTIES ARE FOR ICE
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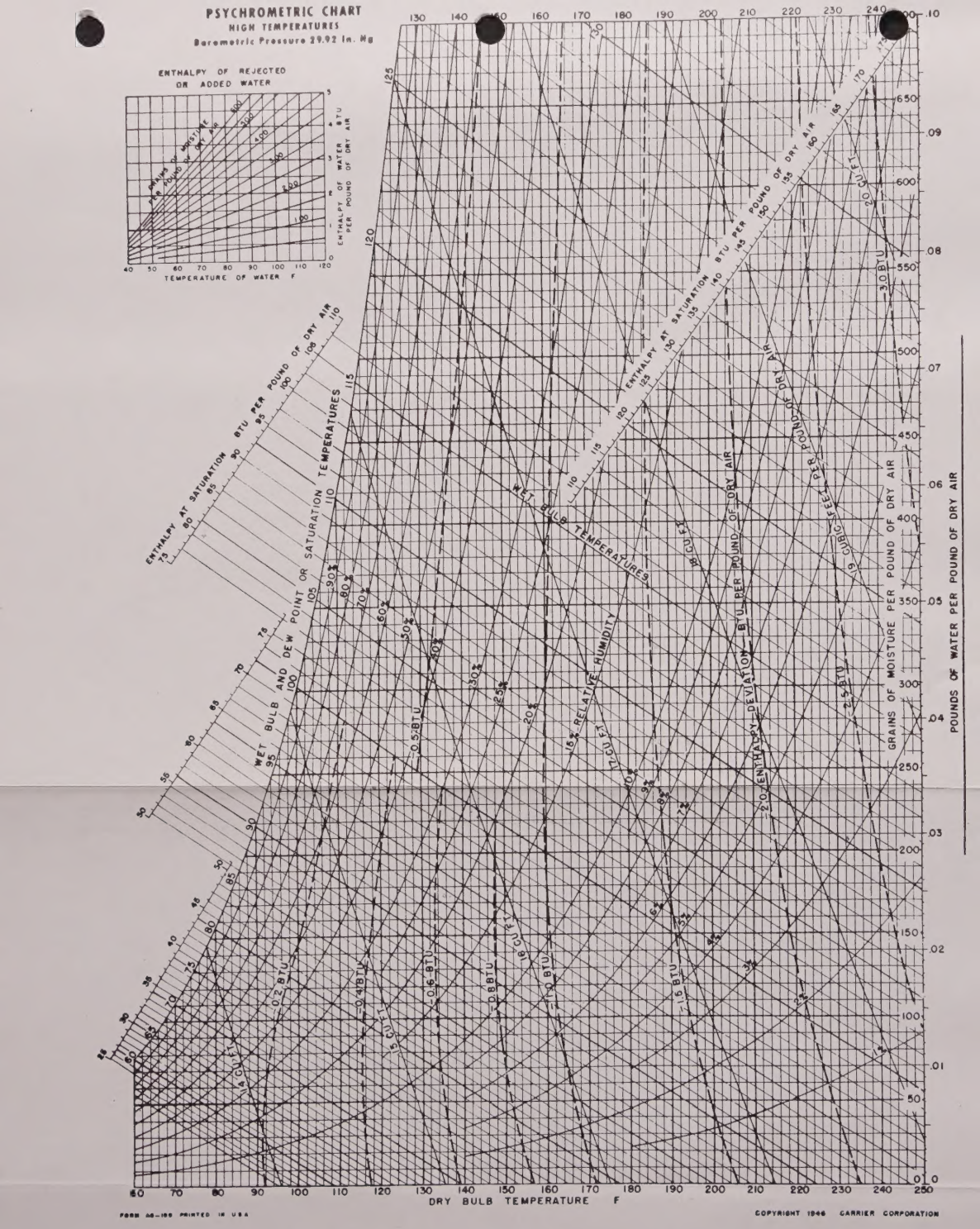
PSYCHROMETRIC CHART
HIGH TEMPERATURES
Barometric Pressure 29.92 In. Hg
ENTHALPY OF REJECTED OR ADDED WATER
GRAINS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY OF WATER BTU PER POUND OF DRY AIR
TEMPERATURE OF WATER F
ENTHALPY AT SATURATION BTU PER POUND OF DRY AIR
WET BULB AND DEW POINT OR SATURATION TEMPERATURES
WET BULB TEMPERATURES
RELATIVE HUMIDITY
CUBIC FEET PER POUND OF DRY AIR
ENTHALPY DEVIATION — BTU PER POUND OF DRY AIR
GRAINS OF MOISTURE PER POUND OF DRY AIR
POUNDS OF WATER PER POUND OF DRY AIR
DRY BULB TEMPERATURE F

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